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CONTENTS

The Mode of Chromosome Reduction — Reginald Ruggles Gates

Filices Wilsonianae — H. Christ

Two Epiphytic Algae — Julia W. Snow

The Development of the Spores in Pleurage zygospora — I. M. Lewis

Notes on Ginkgo biloba — Walter W. Tupper

The Origin of the Chloroplasts in the Cotyledons of Helianthus annuus — Edwin C. Miller

Briefer Articles

Two Sprouting Conifers of the Southwest — F. J. Phillips

Cell Division in Lyngbya — William H. Brown

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THE
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THE MODE OF CHROMOSOME REDUCTION[1]

REGINALD RUGGLES GATES

In 1894 STRASBURGER (**22**), in his well-known paper in the *Annals of Botany*, placed the alternation of generations in plants on a chromosome basis, and showed that not only does a reduction of the chromosomes take place which marks the passage from sporophyte to gametophyte, but that the reduced or gametophytic number is phylogenetically the primitive number, the dominance of the sporophyte with the diploid number in the life cycle having been reached chiefly in the higher phyla of plants.

The stimulus to investigation resulting in part from that paper has led to two results: (1) the determination, for many members of each plant group, of the point in the life cycle where reduction occurs; and (2) the detailed investigation of the exact method by which the process of chromosome reduction is effected. The former line of activity has led to a clear understanding of the life cycle in nearly all plants, and is therefore of fundamental significance for plant morphology. The latter line of inquiry has led to the expression, during the last fifteen years, of a great variety of opinions concerning the precise nature of the reduction process, such opinions affecting fundamentally our conceptions regarding the nature of the chromosomes themselves and the part they play in hereditary processes. These cytological investigations, having gone forward simultaneously on plants and animals, have served to prove the fundamental unity and universality of meiotic phenomena in sexual organisms, so that the present-day cytologist

[1] The main features of this paper were presented by invitation before the National Academy of Sciences, St. Louis Meeting, November 8, 1910.

must take cognizance of the extensive literature on this subject concerning both plants and animals, and also the rapidly developing field of experimental cytology, in making his interpretations and drawing his conclusions. Nowhere is the fundamental unity of all organic matter better exemplified than in the study of these nuclear processes.

It is not my purpose to trace the history of the many changes of opinion regarding the method of chromosome reduction which have occurred as our knowledge of this process has developed. I wish merely to consider certain of the current views, and to express my own point of view, which has resulted from careful studies of reduction in various races and species of *Oenothera*, and the comparison with many other forms,[2] both from preparations and from the literature, as well as from a consideration of the many important data from experimental cytology, and the crossing of forms whose chromosomes differ in number or in morphology. This point of view, therefore, results from the consideration of data bearing on the chromosome question from every angle, so that it would be useless to attempt a citation of all the facts upon which it is based. Nor shall I attempt in this paper to formulate a complete hypothesis of chromosome behavior, nor of the precise hereditary rôle of the chromosomes. My special endeavor will be to show how the chief divergent current opinions regarding meiosis may be unified and harmonized. This will of course involve incidentally the expression of certain views regarding the nature of the chromosomes themselves. I regard it as the duty of every discoverer of new facts to bring them into relation, and if possible into harmony, with the other authenticated facts in the same field. The present paper is an attempt to fulfil this function with regard to my own studies on chromosome reduction. To do this in the present state of our knowledge of this process requires that the subject be approached from a broader viewpoint, if the

[2] I am greatly indebted to Professor GRÉGOIRE for kindly giving me the use of his laboratory facilities during my stay at Louvain, and for many animated and critical discussions of current cytological problems. I am also indebted to Professor STRASBURGER for the courtesies of his laboratory, and for the privilege of examining a large number of cytological preparations. I alone, however, am responsible for the views here expressed.

different methods described are to be welded into one. Perhaps it may also be hoped that the viewpoint here developed will help to stimulate some of the further investigations on this fascinating subject.

Much of the confusion and change of opinion with regard to meiotic phenomena have come from the study of different stages of the process at different times. The earlier investigators of this subject devoted their attention almost entirely to the study of the heterotypic chromosomes or "tetrads," and the manner of distribution of the elements of which each was composed. It was chiefly in later studies that the necessity for determining the manner of origin of the heterotypic chromosomes was realized, so that the studies of the last five or six years have been directed mainly to an understanding of the earlier stages of meiosis, from the telophase of the last premeiotic mitosis to diakinesis. These include the leptonema, zygonema, pachynema, and strepsinema stages (names, some of which involve different interpretations), all of which GRÉGOIRE (**12**, p. 239) prefers to include under the general term synapsis. The synizesis, a special name proposed by MCCLUNG (**13**) for the stage when the delicate chromatic threads occupy but a small part of the nuclear cavity, is also included in this period. In this paper I shall use the term synapsis in its more restricted and more usual botanical sense, as equivalent to synizesis.

The later stages of meiosis, from diakinesis onward, are now pretty clearly understood and agreed upon by most cytologists, particularly those who have studied plant forms. It is the events of the earlier stages which are still in dispute. Some of the most useful contributions of the most recent papers have been with regard to the earliest stages of all, from the "resting" reticulum of the spore mother cell to the synizesis condition.

The use of the term "tetrads" as applied to the heterotypic chromosomes by nearly all the earlier students of meiosis, both in plants and animals, has led to much confusion, due to the fact that these bodies exhibit a great variety of forms and appearances, and in many cases are not tetravalent at all, but bivalent or gemini, and are not due to the split of a single body, but to the approxi-

mation of two somatic chromosomes which may or may not show fission. The attempt to interpret bivalent structures as "tetrads" has been a frequent source of error. The significance of the term "tetrad" as applying to the heterotypic chromosomes was of course derived from the supposed theoretical implications, derived from WEISMANN'S distinction between a longitudinal or quantitative, and a transverse or qualitative division of the chromosomes. It was assumed that if the heterotypic chromosomes gave the appearance of being tetrads or tetravalent structures, then they must have originated from two segmentations, one of which was longitudinal of the spirem and the other transverse. This conception has since lost much of its usefulness, and this is a case where the too close adherence to a useful and stimulating theory has tended finally to retard progress. While such a difference is not impossible, it has not yet been shown by critical observation or experiment that there is any fundamental distinction between a longitudinal and a transverse segmentation of a chromosome. But, on the other hand, many facts with regard to chromosome continuity or individuality of a certain type must be regarded as well established. Longitudinal fission of all the chromosomes is regarded as universal in somatic mitoses, and this has frequently been pointed to as a strong argument in favor of the view that a chromosome is composed of qualitatively different portions or bodies arranged along its long diameter, whose equal division and distribution it is the function of this longitudinal fission to bring about. But it may be pointed out that this longitudinal fission of the viscous chromosome bodies may be determined by purely physical forces resulting, for example, from the electrical charges carried by the chromatin particles.

If this were the case, instead of an equal distribution of "ids" to each daughter chromosome, longitudinal fission would mean merely fission for mechanical or physical reasons along whatever becomes the longitudinal axis of the chromosome as it changes from the reticulate condition of the resting nucleus to the compact condition of prophase or metaphase. There is no observational evidence that longitudinal fission means any more than this, nor that in the passage from the alveolate or reticulate condition of the

resting nucleus to the compact condition of the prophase, any particular arrangement of differential units of structure composing an individual chromosome takes place.

Studies of forms whose chromosome group is composed of bodies morphologically unlike (heteromorphic) have shown, for example in various insects, that the chromosomes frequently maintain the same space relationships to each other in each equatorial plate, and therefore also probably during the intervening "resting" conditions of the nuclei. Other clear evidence, given, for example, by BOVERI (1 and 1*a*), leads to the same conclusion. Hence it is probable that the direction of the long axis of the chromosomes, and hence their plane of division, correspond in successive mitoses. It does not therefore follow, from the statements of the last paragraph, that there is no difference between a longitudinal and a transverse division of a somatic chromosome. For even though such a transverse fission may be of no hereditary significance in separating unlike parts of a chromosome, yet it may have an important mechanical significance, and as far as the morphology of the product is concerned, the result of a transverse split of certain chromosomes in a nuclear plate may very well be different from that of a longitudinal fission. STRASBURGER (**25**, p. 437) suggests as an explanation of the heteromorphic chromosomes in such forms as *Funkia*, *Yucca*, and *Galtonia* that the short chromosomes have arisen by the transverse segmentation of certain of the long chromosomes. This may have been a consequence of the differentiation of the parts of such chromosomes, or may have resulted from more purely mechanical causes, but at any rate it furnishes no evidence that successive longitudinal segments of the long chromosomes which maintain their unity are unlike.[3] Therefore, although, phylogenetically considered, transverse segmentations of members of the chromosome group have doubtless occurred in various species, it does not follow that these segmentations have any fundamental hereditary significance,

[3] In a few forms, such as *Ascaris*, having very few chromosomes, they appear to be compound structures, as shown by their fragmentation in somatic mitoses; but in the great majority of forms no evidence of the compound character of the chromosomes is forthcoming.

because the products of the segmentation all remain in the same nucleus and are propagated in each mitosis.

There is, therefore, no satisfactory cytological evidence that the chromosomes are composed of smaller units whose equal division and distribution is brought about in each mitosis. According to the most careful cytological studies, we cannot with any assurance affirm the existence of smaller differential units composing the chromosomes. On the other hand, the many lines of evidence indicating the more or less independent behavior and genetic continuity of the chromosomes within a nucleus from mitosis to mitosis in the vast majority of cases, seems clear and incontrovertible. To the writer, this independence of behavior will find an explanation in some difference, probably of a chemical nature, between the materials of which the individual chromosomes are composed.

That this is insufficient, however, as an entire explanation, seems to be shown by the case of *Oenothera gigas* (GATES **6**). This mutant has 28 chromosomes, double the number found in its parent, *O. Lamarckiana*. As stated in the above-mentioned paper, *O. gigas* probably contains merely a duplicate set of *O. Lamarckiana* chromosomes, although other changes seem to have occurred simultaneously in producing the mutation. The new number of chromosomes persists, however, and this shows that even though certain of the chromosomes are as much alike as two chloroplasts, yet, having occurred in a given nucleus, they will reappear in its descendants. This may be accounted for by the fact that the mitotic mechanism brings about a simultaneous division of all the chromosomes present. But it does not account for the further fact that all these bodies reappear in the prophase of each mitosis, and hence must have maintained their identity in some way while in the alveolated and distributed condition of the resting nucleus.

The lines of evidence which favor this conception of chromosome continuity from mitosis to mitosis are too numerous to enumerate, and since this view in some form is now widely accepted by cytologists, an enumeration is unnecessary in the present connection. One clear result showing the unity in behavior of the chromosomes was found in the hybrid *O. lata*×*O. gigas* (**5**). This hybrid had 21 chromosomes, 7 derived from the *O. lata* egg and

14 from the *O. gigas* male cell. In reduction they segregated regularly into groups of 10 and 11. The recent work on animal species and hybrids with heteromorphic chromosomes, by BOVERI, BALTZER, HERBST, TENNANT, and others, including the remarkable cases in which certain chromosomes are extruded, is all a confirmation of the same point of view.

We have thus reached the view that, while the chromosomes clearly behave as more or less independent units of structure, we are not justified by observational evidence in assuming that they in turn are composed of smaller morphological units. Further, what has frequently been interpreted as a transverse segmentation of the spirem or of the meiotic chromosome gemini is now known to be, in most cases at least, only the separation of whole somatic chromosomes. It may therefore be questioned whether a transverse fission of the chromosomes themselves ever regularly occurs. As already pointed out, however, this may be for purely mechanical or physical reasons.

From this point of view let us now examine the question of the method of chromosome reduction. In former papers (**4**, **5**, **7**) I have shown that reduction in *Oenothera* takes place according to the FARMER and MOORE method of telosynapsis, the spirem segmenting into a chain of chromosomes arranged end-to-end. In the heterotypic mitosis these (somatic) chromosomes, which may or may not be visibly in pairs, are segregated into two groups at the poles of the spindle. Each of these chromosomes undergoes a longitudinal split during the anaphase or telophase of the heterotypic mitosis, and the halves thus produced are distributed by the homotypic mitosis. The essential and critical stages which show that this is the method of reduction in *Oenothera* were presented in my paper of 1908. The suggestion of GRÉGOIRE, in his very useful summary of the literature of chromosome reduction (**12**, p. 325), that a strepsinema stage had been omitted between the pachynema and diakinesis, cannot apply. It is evident from an examination of figs. 18–32 in my paper already referred to (**4**) that such a stage cannot be intercalated. Especially figs. 18, 22, 23, and 24 leave no room for any other interpretation than the obvious one that a pachynema thread is segmenting into a chain

of chromosomes. Nothing but the exigencies of a theory would tempt anyone to suggest any other explanation. GEERTS (**10**), afterward confirmed by DAVIS (**2**), has reached the same conclusion.

I therefore regard it as certain that in *Oenothera* the pachynema segments directly into a chain of chromosomes arranged end-to-end. That one can reach such a degree of certainty on this point is largely due to the peculiarly favorable character of these critical stages in *Oenothera*, the chromosome number being small (14) and the chromosomes themselves being relatively short and stout, so that the difficulties attending the interpretation of the long threadlike chromosomes are not encountered here.

While, therefore, an end-to-end arrangement or telosynapsis of the chromosomes occurs in *Oenothera*, I think there is also adequate evidence of a side-by-side pairing, or parasynapsis, in certain other forms. I have presented this point of view in several papers (**4, 5, 7**), and have been further confirmed in it by my studies in other laboratories.

It is not necessary to specify here all the plants which are demonstrably telosynaptic, and those which are believed to be demonstrably parasynaptic, but a few of the cases which are best established may be cited. Among recent accounts, in addition to *Oenothera*, telosynapsis in plant forms seems to have been adequately shown by YAMANOUCHI (**28**) in *Fucus*. The most convincing recent accounts of parasynapsis have been by GRÉGOIRE (**11**) with figures of *Lilium*, *Osmunda*, and *Allium;* ROSENBERG (**18**) for *Drosera;* and YAMANOUCHI (**27**) for *Nephrodium*. In *Galtonia*, STRASBURGER first (**23**) gave a telosynaptic account. Later, MIYAKE (**14**) in STRASBURGER'S laboratory decided for parasynapsis. In certain of the later stages, *Galtonia* evidently resembles *Oenothera*. MIYAKE'S figures (pl. 3, figs. 23–32) indicate the segmentation of a pachynema into a chain of chromosomes. It was only after long search, as MIYAKE states (p. 96), that stages as represented by figs. 17–19 were found, indicating a lateral pairing of long narrow chromosomes (strepsinema). According to the ordinary method of cytological interpretation, he concludes that the latter stage must be intercalated, and that all the chromosomes always pass through the strepsinema stage of his fig. 18. This

interpretation assumes an unwarranted amount of "secondary fusion" between the chromosomes to form a chain, as indicated, for example, in his figs. 23 and 24. It seems to the writer equally justifiable to assume that the apparent rarity of a strepsinema stage is real, and that usually the chromosomes do not pass through such a stage during maturation. This obviates the necessity of finding an explanation for an amount of "secondary fusion" between the ends of the chromosomes, which is not easily accounted for. This has always been a serious stumbling-block for those who affirm the universality of parasynapsis, in which the pachynema is followed by a strepsinema stage.

Let us now inquire what is the exact difference involved between the methods of telosynapsis and parasynapsis as described in current papers. Telosynapsis involves the folding and looping and subsequent segmentation of a single thick thread (pachynema) which may have previously exhibited a split which closed up, to reappear only in the anaphase or telophase of the heterotypic mitosis as a longitudinal split in the components of the heterotypic gemini. Parasynapsis involves the lateral pairing of delicate threads at a stage earlier than the pachynema, their more or less complete fusion to form the pachynema, and their subsequent separation to form the strepsinema stage with paired threads, which, by shortening and thickening and (in the cases where a continuous pachynema or strepsinema spirem is supposed to be formed) transverse segmentation to form chromosome pairs, which when first formed are characteristically composed of two long and narrow threadlike chromosomes lying side-by-side and more or less coiled about each other. Later, by shortening and thickening, these chromosomes may, as in *Drosera* (ROSENBERG **18**), become short and stout, or as in *Lilium* they may remain relatively long and narrow, even in diakinesis and the following metaphase.

I think it can be shown upon analysis that the difference between these two methods of reduction is far less fundamental than has been generally supposed.[4] I further believe that the

[4] A recent important paper by Miss DIGBY (**2a**) is quite in accord with this point of view. Miss DIGBY has made a fresh and careful study of somatic and meiotic divisions in *Gallonia*. She interprets the paired threads in early prophase of the

importance and significance of the synapsis stage, even though this condition is unique in the life cycle, has been greatly overestimated; and that the difference between the prophase of an ordinary somatic mitosis and that of the heterotypic mitosis (that is, the presynaptic and postsynaptic stages, from the resting reticulum of the last somatic mitosis to diakinesis) is much less fundamental in character than generally assumed in the current literature. The main fact of reduction, according to the most careful studies of either the telosynaptic or the parasynaptic method, is that in the heterotypic mitosis, instead of dividing, the chromosomes (which represent whole somatic chromosomes) segregate. Nor is there any adequate evidence that the mechanism of meiosis is meant to accomplish anything more than this. The reduction divisions have been studied without sufficient comparison with somatic mitoses, and it is probable that various features of the postsynaptic stages will be found to be devoid of any greater significance than attaches to corresponding spirem stages in the prophases of ordinary mitoses. Theories based on a supposed interchange of "chromomeres" or other materials during certain stages of the heterotypic prophase can be cast aside as having no cytological foundation in critical observation. The most careful recent studies have failed, not only to find any evidence for an interchange of chromomeres, but even to substantiate the idea that the chromatic threads are composed of linin in which chromatin granules are imbedded. The careful observations of GRÉGOIRE and others have served to show that the threads are composed of one general material, the varying density or alveolation of which may give the appearance of granules.

heterotypic mitosis as representing the two edges of a single alveolated chromosome, and therefore equivalent to the similar paired structures in any somatic prophase. The apparently greater definiteness of the zygonema threads, however, would perhaps indicate that the structures represented in the two cases are not necessarily always the same. Regarding the synaptic pairing she says: "The important point which *Galtonia* demonstrates is that its spireme is univalent. Whether these univalent strands join with their homologous pairs telosynaptically or parasynaptically, or by any other intermediate method between these two extremes, resolves itself merely into a question of non-essential detail." Since *Galtonia* is a form having both long and short chromosomes, this perhaps accounts for the great variety observed in the method of pairing. Possibly if the individual chromosomes can be followed it may be found that the longer ones are more likely to pair parasynaptically and the short ones telosynaptically.

Others, for example OVERTON (**17**), have suggested that even though there is no exchange of bodies between the paired threads of the presynapsis, yet the purpose of this pairing may be to bring the threads within each other's "influence." A little reflection, I think, will show the futility of this idea. In *Oenothera* the nuclei of the pollen mother cells have an average diameter of less than 10 μ. The diameter of the presynaptic threads may be taken to be not more than 0.27 μ. Supposing the presynaptic threads to come to lie within their own diameter of each other, it is not clear what chemical or other "influence" could be exerted at the latter distance, which could not be exerted at the former. When it is considered that the chromosomes of the synaptic nuclei have, in higher plants, gone through hundreds of thousands of divisions since they were first associated at the time of fertilization, and that between every two divisions were periods in which the chromosomes were in the alveolated and distributed condition of the "resting" nucleus, in which the portions of the reticulum representing each chromosome must come into the most intimate contact, at least at their boundaries; and when it is further considered that during all this time active metabolic interchanges between nucleus and cytoplasm are taking place, the idea that a pairing of chromosomes or threads at synapsis is necessary for an exchange of influences loses its force.

This leads to another series of facts which students of reduction have frequently failed to take sufficiently into account, namely, that in somatic mitoses the homologous chromosomes are in pairs. MONTGOMERY (**15**) first suggested, in 1901, that in reduction homologous chromosomes of maternal and paternal origin pair. In the following year SUTTON (**26**) showed that in *Brachystola magna*, in which various shapes of chromosomes occur, those of like shape are paired in the spermatocytes. The same thing has since been shown for many other animals, and also for various plants. In 1905 STRASBURGER (**24**) found that this paired condition is not confined to the heterotypic or synaptic chromosomes, but occurs also in the somatic tissues. This was shown by studies of *Galtonia* and *Funkia*, in which the chromosomes are heteromorphic,

being of different lengths. The same thing has since been found to be the case in several other plants having morphological differences in their chromosome group. GEERTS (**9**) published two figures indicating that in *Oenothera*, in which the chromosomes exhibit no morphological differences (that is, are isomorphic), they are also in pairs in the somatic tissues. Two figures (9 and 10) in a subsequent paper of mine (GATES **5**) show indications of the same thing. Therefore, though this cannot be so clearly demonstrated in organisms whose chromosomes are isomorphic, yet it cannot be doubted that the chromosomes are in homologous pairs throughout the somatic cells. OVERTON (**17**) gives indications of this in *Thalictrum* (pl. 1, fig. 1), and believes (p. 45) that the homologous parental elements are finally brought side-by-side in the somatic nuclei. CLEMENS MÜLLER (**16**) has recently given a particularly clear demonstration of this paired arrangement, from studies on the root tips of *Yucca* species, in which the chromosomes are either very long or very short.

From these results it is evident that the pairing of homologous chromosomes is not brought about at synapsis or any other period of meiosis, but that the chromosomes are really paired throughout the life cycle of the sporophyte. The pairing must therefore have taken place at the time of fertilization. One of the best contributions that could be made to the study of the life cycle would be the determination of just how the two single sets of x chromosomes in the egg and sperm nuclei become, in the nuclei descended from the fertilized egg, a set of $2x$ chromosomes arranged in homologous pairs. The idea that the final act of fertilization, that is, the pairing of homologous chromosomes, is deferred until synapsis, an idea which has been often expressed, is therefore a mistaken one, and views of synapsis and its importance in the life cycle will have to be modified accordingly. The view that the function of synapsis is to bring about a pairing of chromosomes or of spirems is no longer justified, (1) because the chromosomes are now known to be paired throughout the somatic tissues of the sporophyte, (2) because there is no satisfactory evidence of a smaller unit of structure within the chromosomes whose union or exchange could be brought about if the materials were stretched out into slender

parallel threads, and (3) because even if there were such units they would have an equally good or even better opportunity for interchange during the alveolated reticulum stage which always intervenes between somatic mitoses.

From this point of view, the life cycle of any sexual plant or animal (with reservations for the Ascomycetes and other groups where peculiar conditions of sexuality occur) may be outlined as follows: At or soon after fertilization, the materials composing the sets of chromosomes of the egg and sperm nuclei become arranged in pairs, so that in subsequent mitoses throughout the sporophyte or soma they always reappear as pairs of homologous chromosomes, the members of which originated respectively from the egg and the sperm or male cell. Synapsis plays no special part in the pairing, and indeed appears occasionally to be omitted in some forms.[5] Meiosis or reduction consists essentially in the segregation of the members of these pairs which have been in association since soon after fertilization. This segregation is followed immediately by what is essentially another mitosis. The gametophytic or germ cell nuclei may then continue to divide with the haploid number of chromosomes until the diploid number is restored by fertilization. The chromosomes are therefore in pairs from the time of fertilization onward, and the members of the pairs are merely segregated in the heterotypic mitosis. The completion of the act of fertilization is not deferred until synapsis, but takes place probably soon after the union of the sexual nuclei; and throughout the sporophyte or soma the chromosomes maintain, to some extent, their relative space relations with each other.

This leaves several obvious points unexplained. Why are there almost universally *two* meiotic divisions without a growth period of the chromosomes between them? The conception of

[5] GRÉGOIRE (**12**, p. 332) says regarding synapsis: "Le ramassement synaptique ne peut avoir, par lui-même, aucun rôle à jouer dans l'accomplissement des phénomènes de réduction, mais doit être considéré plutôt comme une conséquence des phénomènes essentiels qui se déroulent dans le noyau. Cela résulte de ce que, dans certains objets, on ne retrouve pas le ramassement synaptique (SCHREINER, JANSSENS, DETON) et que néanmoins les stades leptotènes, pachytènes (et même zygotènes) y montrent une évolution absoluement identique à celle que l'on constate dans les objets où se manifeste un ramassement."

BOVERI (1) answers this question. After each mitosis, the chromosomes, and also the nuclei and cytoplasm, must grow before they divide again. Otherwise they will all continue to diminish in size. In tissues whose cells are of approximately equal size, the chromosomes must grow to their original size after each mitosis. At the beginning of meiosis, the chromosomes undergo the usual growth, so that, although the individuals are separated into two groups in the heterotypic mitosis, they must still divide again immediately before they are in condition to undergo further growth. GRÉGOIRE (**12,** p. 383) therefore suggests that the heterotypic mitosis is a process of chromosome separation intercalated between the last and the next to the last division of the diploid generation.

If the mere separation of the chromosomes whose ancestors have been in close association throughout the sporophyte is the function of meiosis, then the peculiarly characteristic phenomena of synapsis are without an explanation. In a paper on reduction in *Oenothera* (**4**), I referred to the size relationships of the cells and nuclei in the archesporium and the pollen mother cells. It was pointed out (p. 5) that the cells and nuclei of the sporogenous tissue continue to grow simultaneously from the size indicated by figs. 1 and 2 to that indicated by fig. 4 of that paper. Then (p. 7) the pollen mother cells cease to grow, while their nuclei continue enlarging. This is shown by comparing figs. 4 and 13. During this later growth of the nuclei, synapsis occurs. In figs. 4–10 of the paper cited, the nuclei are all of similar size and are taken from presynaptic cells in the condition shown by fig. 4. In all the later figures (12–32), which are during or after synapsis, the nucleus is seen to be conspicuously larger. A comparison of fig. 4 with figs. 12 and 13 makes it evident that the synaptic "contraction" is partly only an appearance, due to the sudden growth of the nucleus, that is, an increase in the amount of the karyolymph. Occasional threads remain attached to the nuclear membrane and are drawn outward as the nucleus enlarges (cf. figs. 12 and 13). There is also some contraction, however, as shown by comparing the diameter of the reticular area in figs. 12 and 13 with that of the nucleus in fig. 4. In fig. 15, which represents a typical "synaptic ball," it is also evident that the diameter of this ball is less than that of the

nucleus in fig. 4, and it is equally evident that the threadwork in the synaptic ball is much denser than that in the reticulum of fig. 4. Undoubtedly the most important thing that is going on at this time is a rearrangement of the threads of the reticulum to form the more or less continuous threadwork of synapsis. But similar rearrangements go on in the prophase of every somatic mitosis. The peculiar appearance is given to synapsis, and in some degree to the subsequent stages up to diakinesis, by the enormous growth of the nuclear cavity; but, as already pointed out, there is also a certain amount of contraction as the threads of the reticulum become transformed into those of the synaptic ball. In the paper cited I interpreted synapsis in the ordinary way, as resulting from a contraction, but it is evident that this only partly explains the phenomenon, which is largely due to an increase of the karyolymph, accompanied by a rearrangement, without any growth, of the chromatic threads.[6] It is to be hoped that future students of reduction will make careful series of measurements, to see whether the same size relationships hold for other forms. In making such measurements it will be necessary to take account of the fact that in the later stages of synapsis the nuclear membrane frequently becomes extremely delicate or practically disappears, allowing the cytoplasm to encroach on the nuclear

[6] In a conversation with Dr. LAWSON at Brussels during the Botanical Congress, he first suggested to me that the synaptic appearance is due to a growth of the nucleus rather than a contraction of the nuclear contents. He has since kindly sent me an advance proof of his paper (**12***a*), the appearance of which was unfortunately delayed, so that I might make more extended reference to it. In studies of the pollen mother cells of *Smilacina* at the time of synapsis, he finds no contraction whatever of the chromatin. From a series of measurements of the presynaptic and synaptic nuclei in *Oenothera*, I find, as above stated, a slight amount of contraction in the area occupied by the nuclear reticulum (though this probably has no special significance), but a very large growth of the nucleus without a corresponding amount of growth in the cytoplasm. Our results, therefore, are essentially in agreement. LAWSON attributes the growth of the nucleus in the pollen mother cell to the fact that the latter is charged with food materials, which leads to the disappearance of vacuoles from the cytoplasm, and an accumulation of sap within the nuclear cavity. The fact that synapsis is now known to be almost coextensive with sexuality itself, occurring even in Myxomycetes (OLIVE), would seem to call for a more general explanation of the phenomenon. Later in the present paper I have suggested the direction in which it seems probable to the writer that the explanation of the nuclear growth without chromatin growth, which causes the synaptic appearance, is to be found.

area. Measurements should therefore be made only on nuclei whose membrane is distinct; and of course where nuclei are cut by the knife, only sections should be measured which pass through their greatest diameter.

The fact that, at the beginning of the so-called synapsis period, a conspicuous growth of the nucleus of the pollen mother cell takes place, without an appreciable growth in the size of the cell, means that there must be at this period a readjustment in the Kernplasma relation (HERTWIG). In another paper (**6**) considerable attention was devoted to this matter of the Kernplasma relation in *O. gigas*.

It is known that in all higher plants the pollen mother cells first undergo a large amount of growth, in which the nucleus and cytoplasm share simultaneously. In *Oenothera*, as here stated, and probably also in many other plant and animal forms, the nucleus then undergoes further growth, while the cytoplasm remains stationary. The earlier growth of the nucleus of the pollen mother cell is accompanied by a corresponding growth in its chromatic content, so that the reticulum continues to fill the nuclear cavity; but its later growth is due merely to an increase in the karyolymph, while the amount of chromatin ceases to grow, and the reticulum therefore ceases to occupy the whole of the nuclear cavity. During this later nuclear expansion, the chromatin begins the series of rearrangements which change the reticulum to the spirem condition and finally to diakinesis, and which do not necessarily differ in any fundamental particular from the prophases of any somatic mitosis. The peculiar appearances at this time, as compared with somatic prophases, are partly the result of the fact that the rearrangements go on in a much larger cavity, which allows the chromatic materials to be more loosely distributed; while the peculiarities of the diakinesis and the heterotypic gemini may be partly accounted for by the fact that the members of the pairs, instead of lying parallel, usually occupy a great variety of positions relative to each other. Furthermore, in many forms the attraction between homologous chromosomes is probably greater at this time than in somatic mitoses, for the heterotypic gemini are often more closely paired than the chromosomes during the sporophytic divisions.

However, this is not invariably true, and I have shown that in *Oenothera Lamarckiana* and its mutants, and in *O. biennis* (**4** and **5**, p. 183), the diakinetic chromosomes are usually very loosely paired, owing to a weak attraction between homologous chromosomes.[7] In *O. grandiflora*, as I have already pointed out (**7**), the figures of DAVIS (**2**) indicate that this attraction is greater than in the other forms.

It is not to be supposed that these suggestions offer a full explanation of all the phenomena, but they deserve to be carefully tested in future studies of synapsis. The nuclear enlargement unaccompanied by cytoplasmic growth is probably connected with the fact that two subsequent mitoses, without further chromatin growth, follow each other.

A recent paper by STOMPS (**21**), on reduction in *Spinacia*, offers some particularly accurate figures of the presynaptic stages (pl. 1, figs. 7–13), drawings of which have been so frequently more or less diagrammatic. STOMPS finds that the chromosomes are never joined to form a continuous spirem, but that their free ends can always be determined. There are 12 somatic chromosomes in *Spinacia*, and in the presynaptic nuclear reticulum STOMPS believes he is able to determine definitely 6 elongated threadlike darker-staining bodies, which are not joined end-to-end, but variously arranged. Each of these bodies is considered to be composed of two longitudinal portions more or less completely fused, which are interpreted as representing two chromosomes laterally paired. These threads are so delicate that interpretations are extremely difficult, so that the correctness of this interpretation must depend upon the accurate demonstration of the number of these bodies. In later stages the threads are very much shorter and thicker, but the figures (pl. 2, figs. 6–13) do not form a close enough series to show whether the final chromosome bivalents are formed by a longitudinal or a transverse segmentation of the 6 (?) bodies represented in the presynaptic stages. If the author's

[7] In December 1908, in a paper read before the Botanical Society of America (Further studies of Oenotheran cytology; abstract in *Science* **29**:269. 1909), I showed that the phenomena of reduction in *O. biennis* and in *O. laevifolia* agree in every detail with my earlier account (**4**) of that process in *O. Lamarckiana* and its mutants.

interpretation is correct, then we have here, somewhat as in ROSENBERG's account for *Drosera*, a lateral pairing of long thread-like chromosomes, which afterward by contraction become short and thick.

It has sometimes been urged as an argument for the parasynaptic method of reduction, that the chromosomes are in pairs side-by-side in the somatic mitoses. When, as is very generally the case in somatic mitoses, the long axis of the chromosomes is several times their short axis, then for mechanical reasons, if they are to continue to keep together in pairs, they will naturally lie side-by-side in the crowded somatic nuclear prophase and metaphase. The same is true of *Oenothera* (as already referred to in this paper), in which the somatic chromosomes are from three to six times longer than broad. They are paired side-by-side in the equatorial plate of somatic divisions. It is not yet known whether in prophase they lie paired side-by-side or end-to-end on a spirem, though the latter is probably the case. But in any case, they are clearly arranged end-to-end in the stages of reduction preceding diakinesis, though after the looped and folded chain segments, they frequently come to lie paired side-by-side. Such pairs, as I have pointed out in previous papers, are almost invariably joined by a linin connection at *one* end, showing clearly their manner of origin. This all goes to prove that while both end-to-end and side-by-side pairings of chromosomes occur, yet no great significance attaches to the difference. In the case of the heteromorphic chromosomes figured by C. MÜLLER (**16**) in root tips of *Yucca*, the long chromosomes lie in pairs side-by-side, but in the practically globular chromosomes both axes are of the same length, and the distinction between a lateral or endwise pairing breaks down.

Miss STEVENS (**20**) has shown that in one of the mosquitoes (*Culex*) "parasynapsis of homologous chromosomes often changes to telosynapsis in the metaphase of the first spermatocyte." She says (p. 216): "It is of especial interest to see in *Culex* a perfectly clear case of parasynapsis change in some cases to an equally clear case of telosynapsis before metakinesis, while intermediate ring stages and cases of overlapping ends also occur."

The general point of view resulting from the foregoing studies and considerations may now be briefly stated. Both the telosynaptic and the parasynaptic methods of reduction occur, but the difference is not of phylogenetic significance, depending rather upon the mechanics of nuclear processes. In forms having long threadlike chromosomes, the pairing may be expected to take place side-by-side and a strepsinema stage is therefore likely to occur, while with forms having short stout chromosomes, the pairing is, on account of the different spatial relations, more likely to be end-to-end, the pachynema segmenting directly into a more or less continuous chain of chromosomes. In the same form (for example, in *Oenothera*) the somatic chromosomes may be laterally paired in metakinesis, while the heterotypic gemini are at first arranged end-to-end, later frequently swinging round so as to lie side-by-side. It is probably true, as already pointed out, that the chromosomes in somatic prophases in this genus are also at first arranged endwise. This requires further investigation.

It is also evident that the difference between parasynaptic and telosynaptic pairing in meiosis is devoid of hereditary significance, for reasons already stated. Since the chromosomes are in homologous pairs from the early divisions of the fertilized egg onward, the need for a synaptic contraction to bring about an exchange of particles or influences is imaginary. The synaptic contraction is instead (at least in some forms) in large part an appearance, due to an inordinate increase in the karyolymph at this time. The main established facts regarding the life cycle are that the chromosomes are in homologous pairs throughout the sporophyte, and that the members of the pairs are segregated in the heterotypic mitosis.

I may call attention to the fact that, although reduction consists simply in segregation of the descendants of homologous chromosomes which were first associated as pairs soon after fertilization and remained so associated throughout the sporophyte or soma, yet the orientation of these bodies in the heterotypic metakinesis permits varying distributions of the respective mater-

nal and paternal chromosomes during reduction. This is of particular interest from the standpoint of hybrids, but will not be discussed further in this connection.

A striking proof that a redistribution of characters occurs in sexual but not in asexual or vegetative reproduction is to be found in the case of potatoes. The recent experiments of EAST (**3**) and of SALAMAN (**19**) show that potato varieties grown year after year from tubers usually continue true. But when the flowers are self-pollinated the first generation of offspring may show plants of different types. Thus a race of potato with red tubers may on self-pollination produce sexual offspring some of which bear only red tubers and others only white. Here is direct evidence that a segregation and redistribution takes place in sexual reproduction which is absent in vegetative reproduction, or occurs only in the rare cases of "bud sports," through the loss of a character.

The chances for chromosome redistribution during the process of segregation in the heterotypic metaphase certainly furnish the most probable basis for this segregation and redistribution of characters. But as I have pointed out elsewhere (**8**, p. 211) from the evidence of hybrids, this redistribution of characters must also occur in certain cases at other points in the life cycle.

Summary

Studies of chromosome reduction in different plants indicate that there are two general methods of reduction in organisms, one involving a telosynapsis or end-to-end arrangement of the chromosomes, the other involving a parasynapsis or side-by-side pairing. The difference, however, is not of phylogenetic significance, because both methods may occur in different genera of the same family; nor is it of hereditary significance, because the whole chromosome must be regarded as the unit of nuclear morphological structure.

In general, genera having short chromosomes will show telosynaptic pairing, while in forms with long threadlike chromosomes the chromosomes are likely to pair parasynaptically. In organisms having heteromorphic chromosomes, both methods of pairing may occur in the same nucleus. Whether the pairing shall be end-to-end or side-by-side is therefore not of phylogenetic or hereditary

importance, but is merely a matter of cell mechanics; and the two methods of chromosome reduction are therefore essentially one.

While the behavior of the chromosomes affords abundant evidence of some type of individuality or genetic continuity, yet there is no satisfactory evidence of any smaller unit of structure within the chromosome, and for this and other reasons there can be no hereditary difference between a parasynaptic and a telosynaptic pairing of chromosomes.

The one essential and probably almost universal fact of meiosis or reduction in sexual organisms is the segregation of whole somatic homologous chromosomes in the heterotypic mitosis. The reduction process is everywhere the same in involving a segregation of the somatic chromosomes in the heterotypic mitosis, and a split of these chromosomes in the homotypic.

Since it is now known that the chromosomes are in homologous pairs throughout the tissues of the sporophyte, this pairing must take place soon after the association in the fertilized egg of the two sets of chromosomes derived respectively from the egg and sperm nuclei.

The fact that these homologous chromosomes are closely associated in pairs throughout the sporophyte, deprives synapsis of its supposed function of bringing about an interchange of materials or "influences" just before the chromosomes finally separate.

If, as seems evident, the essential fact of meiosis is the mere segregation and redistribution of the chromosomes whose ancestors have been associated in pairs throughout the sporophyte, then the phenomena of the heterotypic prophase do not differ essentially from those of any somatic prophase.

The unique condition of synapsis or synizesis is considered to be due, in some forms at least (for example, in *Oenothera*), to a sudden growth in the nucleus of the pollen mother cell without corresponding growth of the cytoplasm or of the nuclear reticulum. There appears also to be some contraction of the chromatic threads in the nucleus at this time, but the most important change is a rearrangement of the threads from the reticular to the spirem condition.

The conspicuous appearance of "emptiness" of the synaptic

nucleus is largely due to its sudden expansion by an increase in the karyolymph. This involves a sudden change in the karyoplasmic relation, which is probably connected with the fact that, without further chromatic or cytoplasmic growth, two mitoses, one of which involves a segregation and the other a split of the chromosomes, take place in quick succession.

Synapsis, therefore, has no special significance in the life cycle, but depends upon a temporary change in the karyoplasmic relation, which is necessitated by the segregation process, intercalated between two mitoses, one of which (in plants) is sporophytic and the other gametophytic.

Since the life cycle involves a pairing of homologous chromosomes at the time of fertilization and their continued association in pairs until they are separated in the heterotypic mitosis, synapsis is not the delayed and final act of fertilization, as frequently interpreted. Conceptions of synapsis as bringing about an interchange of chromomeres or particles in the chromosomes are not supported by critical observations; and ideas involving an exchange of "influences" are rendered superfluous by the fact that the homologous chromosomes are paired throughout the sporophyte.

Reduction does not consist in a transverse or qualitative and a longitudinal or quantitative split of the chromosomes according to the conception of WEISMANN, but involves merely a segregation and redistribution of the members of homologous pairs of whole somatic chromosomes. If the most widely accepted general account of reduction be universal, then a transverse segmentation of the chromosomes never regularly occurs. But it may be for purely physical reasons that a somatic chromosome always splits longitudinally. It is not necessary to assume that the function of this split is to produce an equal division and distribution of differentiated "ids" arranged along its axis.

MISSOURI BOTANICAL GARDEN
ST. LOUIS, MO.

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FILICES WILSONIANAE

H. CHRIST

(WITH TWO FIGURES)

[The ferns collected by Mr. E. H. WILSON from 1907–1908 in Hupeh and Szech'uan, during the Arnold Arboretum expedition to western China, were placed in the hands of Dr. H. CHRIST of Basel. His report upon them is found in the following paper.—C. S. SARGENT, *Arnold Arboretum*.]

Province of Hupeh[1]

WOODSIA POLYSTICHOIDES Eat.—Fang Hsien; cliffs, 4000–6000 ft.; August 1907; no. 2602.—J.

DRYOPTERIS DECURSIVE-PINNATA (*Polypodium* Van Hall) O. Ktze.—Patung Hsien; woodlands, 3000–4000 ft.; May 1907; no. 2599.—J.

DRYOPTERIS ROBERTIANA (*Polypodium* Hoffm.) C. Chr. Ind.—Fang Hsien; cliffs, 4000–6000 ft.; August 1907; no. 2627.—E.A.

DRYOPTERIS HENDERSONI (*Lastrea* Bedd.) C. Chr. Ind. (*Aspidium spectabile* Wall.).—Changyang Hsien; woodlands, 3000–4000 ft.; May 1907; no. 2630.—H.

POLYSTICHUM SPECIOSUM (*Aspidium* Don) J. Sm. (*Aspidium affine* Wall.).—Patung Hsién; woods, 1800 ft.; April 1907; no. 2626.—H.

*POLYSTICHUM MUPINENSE (*Aspidium* Franchet) Bedd.—Fang Hsien; cliffs, 4000–6000 ft.; September 1907; no. 2601.

*POLYSTICHUM ICHANGENSE Christ.—Fang Hsien; cliffs, 4000–5000 ft.; August 1907; no. 2609.

POLYSTICHUM ACULEATUM (L.) Schott.—Forma tenera, profunde dentata, caeterum typica.—Hsing-shan Hsien; woods, 4000–6000 ft.; August 1907; no. 2611.—H.J.E.A.

*POLYSTICHUM DEVERSUM Christ, n. sp.—Fang Hsien; woodland, 5000–6000 ft.; August 1907; no. 2625.

[1] I have indicated with an H the species found in India and chiefly on the southern slope of the Himalayan Chain; those found in Japan with a J; those found in Europe with an E; and those found in America with an A. I have indicated with an asterisk (*) the species peculiar to Hupeh and western Szech'uan.

*POLYSTICHUM MOLLICULUM Christ, n. sp.—Fang Hsien; 8000 ft.; June 27, 1907; no. 2657.

*POLYSTICHUM LEUCOCHLAMYS Christ, n. sp.—Fang Hsien; woods, rocks, 5000–6000 ft.; November 1907; no. 2600.

*POLYSTICHUM LOBATUM (*Aspidium* Hds.) Prsl. var. CHINENSE Christ Nuov. Giorn. Bot. Ital. **4**:92. 1897, et Bull. Soc. Bot. France **5**:1905.—Hsing-shan Hsien; 4000–6000 ft.; July 1907; no. 2612.

POLYSTICHUM DELTODON (*Aspidium* Baker) Diels.—Fang Hsien; woods, 5000–6000 ft.; November 1907; no. 2620.

CYRTOMIUM FALCATUM (*Polypodium* L. fil.) Prsl. var. MUTICUM Christ Notulae System. Mus. Paris no. 25. 1909.—Hsing-shan Hsien; woods, 4000–5000 ft.; August 1907; no. 2628.

ODONTOSORIA CHINENSIS (*Trichomanes* L.) J. Sm.—Ichang; roadsides and sunny places generally, 1000–1400 ft.; July 1907; no. 2663.—H.J.

ASPLENIUM PROLONGATUM Hook.—Fang Hsien; rocks, 1000–1500 ft.; August 1907; no. 2655.—H.J.

ASPLENIUM TRICHOMANES L.—Fang Hsien; cliffs, 4000–7000 ft.; August 1907; no. 2659.—H.J.E.A.

BLECHNUM EBURNEUM Christ.—Patung Hsien; moist cliffs, 2000 ft.; July 1907; no. 2678.

CONIOGRAMME FRAXINEA (*Diplazium* Don) Diels.—Fang Hsien; woodland; November 1907; no. 2679.—H.J.

ADIANTUM PEDATUM L.—Fang Hsien; woods, 3000–6000 ft.; July 1907; no. 2672.—H.J.A.

*ADIANTUM ARISTATUM Christ, n. sp.—Fang Hsien; rocks, 3000–4000 ft.; November 1907; no. 2674.

PTERIDIUM AQUILINUM (L.) Kuhn.—Ichang; abundant (starch is obtained from the rhizome), 1000–10,000 ft.; May 1907; no. 2682.—H.J.E.A.

PTERIS LONGIFOLIA L.—Ichang; dry rocks, 1000–3000 ft.; April 1907; no. 2665.—H.J.E.A.

PTERIS CRETICA L. var. SUBSERRULATA Christ, n. var.—Fang Hsien; shady rocks; July 1907; no. 2670.

POLYPODIUM SUBAMOENUM Clarke.—Fang Hsien; 4000–6000 ft.; August 1907; no. 2648.—H.

POLYPODIUM CHINENSE Metten.—Fang Hsien; cliffs, rocks, 3000–6000 ft.; August 1907; no. 2640.

POLYPODIUM EXCAVATUM Bory.—Hsing-shan Hsien; rocks, 2000–5000 ft.; August 1907; no. 2635.—H.J.

*POLYPODIUM LINEARE Thunberg.—Hsing-shan Hsien; rocks, 2000–5000 ft.; August 1907; no. 2635 bis.—H.J.

POLYPODIUM CONTORTUM Christ (*P. lineare* Thnbg. var. *contortum* Christ Nuov. Giorn. Bot. Ital. **4**:1. Jan. 1897–1898).—Fang Hsien; rocks and trees, 4000–6000 ft.; August 1907; no. 2636.

POLYPODIUM CLATHRATUM Clarke.—Fang Hsien; cliffs, 3000–6000 ft.; August 1907; no. 2642.—H.

POLYPODIUM DRYMOGLOSSOIDES Baker.—Fang Hsien; on trees and rocks, 3000–5000 ft.; July 1907; no. 2647.

DRYMARIA FORTUNEI (*Polypodium* Ktze.) J. Sm.—Ichang; abundant on rocks and trees, 1000–3000 ft.; April 1907; no. 2646.

CYCLOPHORUS CALVATUS (*Polypodium* Baker) C. Chr. Ind. 198.—Fang Hsien; cliffs, 3000–6000 ft.; August 1907; no. 2641.

CYCLOPHORUS DRAKEANUS (*Polypodium* Franchet) C. Chr. Ind. 198.—Fang Hsien; cliffs, 1000–6000 ft.; no. 2627.

LOXOGRAMMA INVOLUTA (*Grammitis* Don) Presl. (*Polypodium scolopendrinum* C. Chr. Ind. 562).—Hsing-shan Hsien; 2000–5000 ft.; October 1907; no. 2661.—H.

GLEICHENIA LINEARIS Burm.—Ichang; open country, forming jungles, 1000–3000 ft.; no. 2677.—H.J.A.

OSMUNDA REGALIS L.—Patung Hsien; grassy spots, ravines, etc., 1000–5000 ft.; May 1907; no. 2676.—H.J.E.A.

LYCOPODIUM CLAVATUM L.—Patung Hsien; grassy spots, 5000–6000 ft.; July 1907; no. 2656.—H.J.E.A.

LYCOPODIUM OBSCURUM L.—Fang Hsien; rocks in silver fir forests, 9500 ft.; May 16, 1907; no. 2650.—J.A.

SELAGINELLA CAULESCENS Spring.—Ichang; glen, 1–1000 ft.; May 1907; no. 2654.—H.J.

Province of Szech'uan

HYMENOPHYLLUM BLUMEANUM Spreng.—Mupin; wet rocks, woodland, 4000–6000 ft., August 1908; no. 2681.—H.

WOODSIA DELAVAYI Christ.—Northeast of Ta-tsien-lu; 7200 ft.; July 2, 1908; no. 2616.

DRYOPTERIS CRENATA (*Polypodium* Forskal.) O. Ktze.—Mupin; cliffs, 4000–6000 ft.; August 1908; no. 2631.—H.

DRYOPTERIS MARGINATA (*Aspidium* Wallich Cat. 391).—Mupin; woodland, 4000–6000 ft.; August 1908; nos. 2604, 2632.—H.

*DRYOPTERIS PSEUDOCUSPIDATA Christ, n. sp.—Mupin; woodland, 6000 ft.; August 1908; no. 2603.

DRYOPTERIS DECURSIVE-PINNATA (*Polypodium* Van Hall) O. Ktze.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2618.—J.

POLYSTICHUM PRESCOTTIANUM (*Aspidium* Wallich) Moore.—Ta-tsien-lu; woods, 6000 ft.; June 1908; no. 2622.—H.

*POLYSTICHUM MUPINENSE (*Aspidium* Franchet) Bedd.—Mupin; rocks in woods, 4000–6000 ft.; August 1908; no. 2617.

*POLYSTICHUM OTOPHORUM (*Aspidium* Franchet) Bedd.—Mupin; cliffs, 5000–6000 ft.; August 1908; nos. 2598, 2624.

*POLYSTICHUM WILSONI Christ, n. sp.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2614.

*POLYSTICHUM WOODSIOIDES Christ, n. sp.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2615.

*POLYSTICHUM LACERUM Christ, n. sp.—Mupin; rocks, 4000–6000 ft.; August 1908; no. 2608.

*POLYSTICHUM LEUCOCHLAMYS Christ, n. sp.—Mupin; rocks, 4000–6000 ft.; August 1908; no. 2606.

POLYSTICHUM STENOPHYLLUM Christ.—Mupin; cliffs, 4000–6000 ft.; August 1908; no. 2618.

POLYSTICHUM THOMSONI (*Aspidium* Hook. fil.) Bedd.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2607.—H.

POLYSTICHUM CARVIFOLIUM (*Aspidium* Ktze.) C. Chr. Ind.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2605.—H.J.

SOROLEPIDIUM GLACIALE (*Polystichum* Christ) Christ, n. gen.—Mupin; cliffs, 5000 ft.; August 1908; no. 2613.

CYRTOMIUM LONCHITOIDES Christ.—Mupin; cliffs, 5000–6000 ft.; August 1908; nos. 2621, 2623.

DAVALLIA ATHAMANTICA Christ.—Mupin; cliffs, 4000–6000 ft.; August 1908; No. 2666.

LINDSAYA CULTRATA Sw.—Mupin; cliffs, 4000–6000 ft.; August 1908; no. 2671.

ATHYRIUM NIGRIPES Blume.—Mupin; rocks, 4000–6000 ft.; August 1908; no. 2660.—H.J.

ATHYRIUM PYCNOSORUM Christ.—Mupin; 4000–6000 ft.; August 1908; no. 2656.—J.

*ATHYRIUM MUPINENSE Christ, n. sp.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2610.

ASPLENIUM PRAEMORSUM Sw.—Mupin; cliffs, 4000–6000 ft.; August 1908; no. 2662.—H.A.

ASPLENIUM YUNNANENSE Franchet.—Mupin; cliffs, 4000–6000 ft.; August 1908; no. 2658

BLECHNUM EBURNEUM Christ.—Mupin; wet rocks, 3000–5500 ft.; August 1908; no. 2678.

GYMNOPTERIS VESTITA (*Grammitis* Wallich).—Northeast of Ta-tsien-lu; dry banks, 7000 ft.; February 7, 1908; no. 2668.—H.

*GYMNOPTERIS SARGENTII Christ, n. sp.—Monkong Ting; loamy places, warm valleys, 7000–9000 ft.; June 28, 1908; no. 2669.

PELLAEA NITIDULA (*Pteris* Wallich) Baker.—Northeast of Ta-tsien-lu; dry rocks, 6900–8000 ft.; June 30, 1908; no. 2664.—H.

DORYOPTERIS DUCLOUXII Christ.—Mupin; loamy banks, old walls, etc., 3000–5000 ft.; August 1908; no. 2667.

ADIANTUM PEDATUM L.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2673.—H.J.A.

ADIANTUM VENUSTUM Don.—Mupin; rocks in wood, 4000–5000 ft.; August 1908; no. 2675.—H.

PLAGIOGYRIA ADNATA (*Lomaria* Blume) Bedd.—Hung Yah Hsien; 3000 ft.; September 8, 1908; no. 2680.—H.J.

VITTARIA SUBEROSA Christ.—Wa-shan; on trees and rocks, 5000–7000 ft.; September 1908; no. 2638.

POLYPODIUM SUBAMOENUM Clarke.—Mupin; rocks, 3000–6000 ft.; August 1908; no. 2648.—H.

*POLYPODIUM TALIENSE Christ.—Mupin; rocks, 3000–6000 ft.; August 1908; no. 2649.

POLYPODIUM ANNUIFRONS Makino.—Ta-tsien-lu; rocks in wood, 6000–8000 ft.; June 1908; no. 2637.—J.

POLYPODIUM ENGLERI Luerss.—Mupin; cliffs, 4000–7000 ft.; August 1908; no. 2639.—J.

POLYPODIUM SHENSIENSE Christ.—Mupin; cliffs, 4000–6000 ft.; August 1908; no. 2644.

POLYPODIUM LEHMANNI Metten.—Mupin; woodland, 4000–6000 ft.; August 1908; no. 2643.—H.

POLYPODIUM GRIFFITHIANUM Hook.—Mupin; 4000–6000 ft.; August 1908; no. 2645.—H.

POLYPODIUM LINEARE Thunbg.—Ta-tsien-lu; on trees, 4000–8000 ft.; June 1908; no. 2633; on rocks, no. 2634.—H.J.

LYCOPODIUM LUCIDULUM Michaux.—Northeast of Ta-tsien-lu; rocks, 8000–10,000 ft.; June 1908; no. 2651.—H.A.

Diagnoses of the new species

Sorolepidium H. Christ, genus novum.—Habitu *Ceterach*, characteribus potius *Polystichum* referens, differt soris magnis medialibus in nervulo basali anteriore nervorum lateralium terminalibus, subrotundis, indusio proprio deficiente, indusio spurio squamis singulis vel duabus aut tribus subulatis et fimbriatis e basi receptaculi oriundis constituto.

This beautiful plant, which much resembles a xerophilous alpine Tibetan species, deserves as well as *Plecosorus* to be separated from *Polystichum* by the characters indicated above. The indusial scales are found at the base of the receptacle and are inserted on the vein, arising at the base of the pedicels of the sporangia. There is always one larger scale, and sometimes one or two smaller ones; and also always a very large one inserted on the costa of the pinna and covering the sorus. FRANCHET has placed this plant with *Gymnogramme* in the Paris Herbarium, without naming it, probably because of the confluent sori without indusia; but the sorus does not follow the soriferous vein longitudinally as in *Gymnogramme*, it is attached to a terminal receptacle.

Sorolepidium glaciale (*Polystichum* Christ Foug. de la Chine Mus. Hist. Nat. Paris, Bull. Soc. Bot. France IV. **5**:28), *fig. 1*.

HAB.—Seems widely distributed in the high ranges of western China.

Discovered by Abbé DELAVAY in Yunnan on rocky declivities at the foot of the Lu Kiang glacier, July 9, 1884, n. 45. Herb. Paris. Rediscovered by WILSON in the western part of Szech'uan, 1903–1904, no. 537 (Herb. James Veitch & Sons), Bull. Acad. Geog. Bot. Mans 110, 1906; by the same collector

in the same region, Mupin, cliffs 5000 ft., August 1908, no. 2613 (Herb. Harvard Univ.).

I owe to the kindness of Mademoiselle CHARLOTTE TERNETZ, Ph.D., of Basel, the drawings of the enlarged details of this plant.

Polystichum leucochlamys H. Christ, n. sp.—Rhizomate brevi, pollicis crassitie, radicoso, cum stipite rachique squamis magnis patentibus ovato-acuminatis 4 mm. longis brunneis longe fimbriato-ciliatis, in rachi sensim diminutis et angustatis, fasciculatis et laceratis tecto; foliis fasciculatis, stipite 8–12 cm. longo, viridi aut stramineo 2 mm. crasso. Lamina lanceolato-caudata, ad basin angustata, rachi debili et arcuata praedita, 30 cm. longa 4.5 cm. lata, apice nuda elongata et gemma vivipara instructa, pinnata, pinnis 30–40 utrinque, approximatis sive admodum distantibus, infimis diminutis et reflexis, caeteris patentibus lanceolato-falcatis obtusis rarius acutis, subsessilibus, 2 cm. longis, basi 0.5 cm. latis, basi inaequalibus, postice cuneatis, antice acute auriculatis, crenatis aut decumbenti-serratis, nervis valde obliquis, soris rotundis, marginalibus, uniseriatis margini anteriori insertis, indusiis maximis, 2 mm. diametro, scarioso-hyalinis, imbricatis, bullatis, albidis, diaphanis, umbilicatis, margine minu-

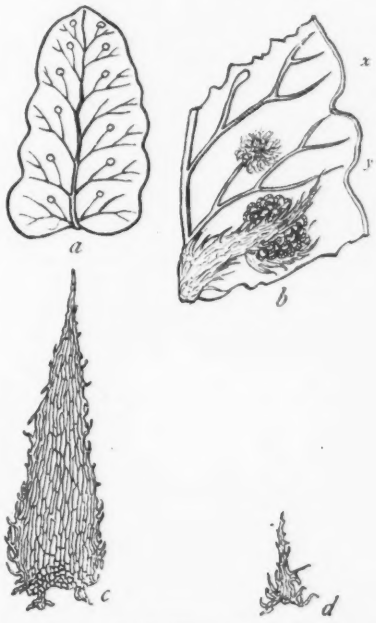

FIG. 1.—*Sorolepidium glaciale* Christ: *a*, larger pinnule, showing circular attachment of sorus (somewhat too strongly marked), ×5; *b*, portion of a pinnule (*x*, end of sorus nervule; *y*, the sporangium stalks still remaining; *z*, sorus with overlying scale from principal nerve and the under scale arising from sorus nerve), ×15; *c*, large scale, ×10; *d*, small scale, ×10.

tissime fimbriato. Faciebus hinc inde setulosis. Textura herbacea, colore dilute viridi.

Facie *P. auriculati* (L.) Prsl., characteribus *P. craspedosori*.

Highly developed form of the type of *P. craspedosorum* (*Aspidium* Maxim.) Diels; distinguished by larger dimensions, elongated stipe, and very broad swollen scarious white indusia. It is surprising to see this species from two localities so widely separated as W. Hupeh and W. Szech'uan.

HAB.—Rocky places, Mupin, W. Szech'uan, 4000–6000 ft., August 1908, no. 2606; woods and rocks, Fang Hsien, W. Hupeh, 5000–6000 ft., November 1907, no. 2600.

Polystichum lacerum H. Christ, n. sp.—Rhizomate brevi, squamis brunneis lanceolato-acuminatis 3 mm. longis fimbriato-ciliatis vestito, foliis coespitoso-fasciculatis numerosis (12) stipite brevi 3–4 cm. longo, stramineo, sed iisdem squamis setulisque cum rachi abunde tecto, lamina 12–15 cm. longa 22 cm. lata lanceolata versus apicem acuminata breviter caudata et gemma minima saepius abortiva terminata, versus basin vix angustata, pinnata, sed pinnis infimis basi profunde et fere ad costam incisis, pinnis ca. 25 utrinque patentibus, inferioribus suboppositis, sessilibus, 1 cm. longis basi 1.5 cm. latis cuneato-ovatis falcatis acutis, basi inaequalibus i.e., antice valde auriculatis, profunde lobatis, lobis ca. 5 utrinque, ovato-obtusis, rarius crenulatis. Soris magnis plerumque uniseriatis margini anteriori insertis, brunneis, sese tangentibus et subconfluentibus, indusio 0.5 mm. lato obscure griseo tenuissimo, sporangiis arctissime adhaerente margine lacerato, demum evanescente. Textura herbacea, facie superiore calva obscure viridi, inferiore hirsuta, pallidiore.

HAB.—Rocks, Mupin, 4000–6000 ft., August 1908, no. 2608.

Member of the group of *P. craspedosorum* (Maxim.) Diels, of the same habit, but with pinnae more scaly and more incised, and with the indusium more delicate and fringed.

These three species (*P. leucochlamys*, *P. craspedosorum*, and *P. lacerum*) form a distinct group of *Polystichum* (CRASPEDOSORA), characterized by marginal sori inserted at the anterior border of the pinnae, by a broad and membranaceous indusium exceeding the sorus, and by the point of the proliferous rachis. The best developed form of the group is *P. leucochlamys*, the least developed is *P. lacerum*. These two seem peculiar to western and central China, while the intermediate form, *P. craspedosorus*, extends throughout China to Japan and Corea.

Polystichum Wilsoni H. Christ, n. sp.—Rhizomate crasso obliquo radicoso atrobrunneo, squamis magnis ovato-acutis scariosis dilute brunneis margine saepe laceratis 6 mm. longis vestito, stipitibus subfasciculatis, 17 cm. longis, luteo-stramineis, 2 mm. crassis, iisdem squamis sparsis, et insuper cum rachi squamis lanceolato-linearibus et subulatis longis albidis setisque vestitis. Lamina 45 cm. longa 10 cm. lata acuminata, versus basin sensim angustata, pinnis infimis remotis valde abbreviatis et deflexis. Lamina bipinnata, pinnis ca. 35 utrinque alternis sessilibus approximatis, 5 cm. longis basi 16 mm. latis acuminatis, basi subinaequalibus i.e., pinnula basali anteriore reducta, pinnulis confertis ca. 15 utrinque, obliquis, sessilibus, oblongis acutis, inaequalibus, postice minus, antice creberrime et profunde biserrato-aristatis, dentibus angustis pectinatis, soris medialibus brunneis confluentibus, indusio inconspicuo fugaci orbiculari minuto, 0.5 mm. lato nigro-umbonato. Facie superiore pilis longissimis lucentibus parce, facie inferiore cum costa costulisque setis longis subulatis albicantibus pilisque abunde vestita. Textura herbacea, colore luteo-virente.

HAB.—Woodlands, Mupin, 4000–6000 ft., August 1908, no. 2614.

Inter *P. aculeatum* (*Polypodium* L.) Schott et *P. Bakerianum* (*Aspidium* Atkins.) Diels intermedium.

Polystichum deversum H. Christ, n. sp.—Rhizomate brevi erecto, squamis latis ovalibus acutis scariosis brunneis vestito. Stipitibus fasciculatis 4 cm. longis, iisdem squamis et minoribus laceratis vestitis, sulcatis, 1.5 mm. crassis. Lamina 33 cm. longa, 3 cm. lata acuminata, versus basin sensim angustata, linearilanceolata, pinnata, rachi straminea, squamis castaneis fasciculatis laceratis variegata, pinnis ca. 45 utrinque, pectinato-confertis, petiolulatis, deflexo-reversis, inaequalibus, 11 mm. longis, basi 6 mm. latis, rhombeo-trigonis, basi posteriore cuneato-abscissis, anteriore acute auriculatis subintegris aut minute crenulatis, nervis confertis ramosis subflabellatis, soris medialibus, remotis, rotundis, ca. 5 utrinque. Facie superiore subglabra, inferiore squamis acutis adpressis ochroleucis tecta, margine breviter ciliato. Textura firme papyracea, colore supra laete virente, subtus pallidiore lutescente.

HAB.—Woodlands, Fang Hsien, W. Hupeh, 5000–6000 ft., August 1907, no. 2625.

Group of *P. deltodon* (Bak.) near *P. stenophyllum* Christ, but distinguished by its larger dimensions, short stiped fronds gradually attenuated toward the base, broad triangular-rhomboidal pinnae hardly dentate and with a dense coating of appressed scales.

Polystichum woodsioides H. Christ, n. sp.—Rhizomate brevi, squamis integris ovatis brunneo-scariosis 3 mm. longis vestito, foliis fasciculato-coespitosis numerosis (10), stipite valido, obeso 1.5 mm. crasso 6 cm. longo flavo-stramineo versus basin atro-brunneo, squamis scariosis dilute brunneis ovatis acutis integris, angustioribus pilisque brevibus mixtis vestito, rachi crassa setulis pallidis pubescente, fronde 15 cm. longa, 23 mm. lata lineari-lanceolata acuminata versus basin angustata, bipinnatifida, pinnis confertis, inferioribus remotioribus et valde diminutis, ca. 27 utrinque, fere sessilibus deltoideo-oblongis, e basi latissima versus apicem obtusum attenuatis, 1 cm. longis, basi 0.5 cm. latis, profunde et ad basin ad costam incisis, segmentis ca. 5 utrinque imbricate-confertis, infimis liberis, superioribus basi connatis, ovatis acutiusculis, minute dentatis, subtus pubescentibus, supra calvis, soris in tertia frondis parte superiore positis, numerosis, 3 aut 4 pro lobo, rotundis, continguis et confluentibus, brunneis, indusio peltato corrugato persistente brunneo minuto, umbone nigro. Textura molliter herbacea, colore supra obscure, subtus pallide virente.

HAB.—Woodlands, Mupin, 4000–6000 ft., August 1908, no. 2615.

Species with very narrow fronds resembling in habit small alpine species of the group of *P. lachenense* (Hook.) Bedd., but belonging rather to the group of *P. mupinense* (Franch.), being bipinnate. Remarkable for the very small but much incised pinnae and thick rachis.

Polystichum molliculum H. Christ, n. sp.—Rhizomate brevissimo radicoso coespitoso, cum stipitis basi squamulis subulatis brevibus sparso. Stipitibus fasciculatis numerosis stramineis filiformibus 3.5 cm. longis, cum rachi raris setulis sparsis, lamina 4 cm. longa, 1 cm. lata, lanceolata obtusa bipinnatifida. Pinnis ca. 4 utrinque suboppositis, sessilibus, late obovatis basi subinaequalibus antice auctis, flabellato-incisis, inferioribus usque ad costam partitis ideoque auriculatis, lobatis, 3 ad 5 mm. longis et

latis, lobis ovato-rotundatis acutis interdum dentatis. Soris magnis, singulis in lobis, demum confluentibus, indusio inconspicuo corrugato. Textura tenuiter herbacea, colore laete virente.

HAB.—Rocks, Fang Hsien, 8000 ft., June 27, 1907, W. Hupeh, no. 2657.

An extremely reduced species, with the habit of a very small *Cystopteris*, distinguished from *P. capillipes* (Baker) Diels by the less incised pinnae with broader segments.

With the six species here described, with which Mr. Wilson has enriched the flora of China, the Chinese species of *Polystichum* now known number 52. There are few examples of so rich and continuous a development without gaps between the different known forms of this genus, so essentially Chinese. The species of *Polystichum* of other regions of the globe seem to be only derivatives or scattered offshoots of this great eastern center.

Gymnopteris Sargentii H. Christ, n. sp.—Rhizomate valido pollicis crassitie, obliquo, setis mollibus 0.5 cm. longis pallide rufis densissime obtecto, radicibus numerosis fasciculatis. Stipitibus subfasciculatis 3 aut 4, flexuosis crassis rigidis 3 mm. diametro, rufostramineis, 8 cm. longis, cum rachi aeque rigida et 2 ad 2.5 mm. crassa costisque tomento albido-fulvo omnino-vestitis, lamina late deltoideo-ovata 20 cm. longa 9 cm. lata abunde bipinnata, pinnis remotis ca. 6 utrinque infra apicem brevem simpliciter pinnatum, erecto-patentibus, infimis suboppositis coeteris alternis, basalibus haud abbreviatis, 7 cm. longis 14 mm. latis, lineari-lanceolatis breviter petiolatis, costa rigida vix 1 mm. crassa, pinnulis ca. 7 utrinque, approximatis, deltoideis obtusis basi late trilobo-hastatis 7 mm. longis 5 mm. latis petiolulatis, rigide coriaceis, supra calvis obscure viridibus, subtus et margine densissime rufotomentosis nitidis. Soris submarginalibus confluentibus.

HAB.—Loamy places in warm valleys, Monkong Ting, W. Szech'uan, 7000–9000 ft., June 28, 1908, no. 2669.

This is the most developed species of the series formed by the three species *G. vestita* (*Grammitis* Wallich) Underw., *G. bipinnata* Christ (Notul. Systemat. Mus. Paris no. 2, p. 23. 1909), and *G. Sargentii*, distinguished by its larger dimensions, and a broadly bipinnate frond with numerous trilobed pinnules. Habit nearly that of *Pellaea hastata* (Thnbg.) Prantl. *G. bipinnata* differs by the slender rachis, elongated lanceolate pinnate to nearly bipinnate fronds, and less incised pinnules.

Athyrium nupinense H. Christ, n. sp.—Rhizomate brevi erecto radicoso, cum basi stipitis setis atrobrunneis flexuosis fere

0.5 cm. longis e verruca oriundis vestito. Stipitibus fasciculatis numerosis (ca. 12) tenuibus flaccidis stramineis 5 cm. longis, lamina 20 cm. longa 5.5 cm. lata acuminata basi aliquantulum angustata lanceolato-oblongo bipinnata. Rachi tenui parce setulosa, planta caeterum calva. Pinnis 25–30 utrinque, alternis, approximatis, recte patentibus, deltoideo-ovatis acutis, petiolulatis basi inaequalibus i.e., pinnula basali anteriore aucta, 2 cm. longis basi 12 mm. latis, ad alam angustam incisis, pinnulis confertis sessilibus, infimis rarius subpetiolulatis, ca. 7 utrinque, oblongis subobtusis, basi subinaequalibus i.e., antice auctis, 1 cm. longis 3 mm. latis, acute sed breviter serratis nec aristatis, soris rotundis vix 1 mm. latis brunneis ca. 4 utrinque, medialibus, haud confluentibus, indusio fugaci reniformi. Textura flaccide herbacea, colore obscure virente.

HAB.—Woodland, Mupin, 4000–6000 ft., August 1908, no. 2610.

Affine *A. demisso* Christ in Fedde Repert. **5**: 284. 1908. Insularum Jezo et Quelpaert, quod differt dentibus aristato-pectinatis. Planta humilis, *A. anisoptero* Christ aut *Cystopteridi* similis.

Adiantum aristatum H. Christ, n. sp.—Rhizomate breviter repente, tenui, squamis subulatis atrobrunneis vestito. Stipite valido, erecto, tereti, atropurpureo nitido, laevi uti tota planta, 1.5 mm. crasso 120 cm. longo. Fronde late deltoideo-ovata, basi rotundata, apice acuta aut obtusa, 13 cm. longa, 9 cm. lata, tripinnata, pinnis pinnulisque imbricato-confertis, brevissime petiolatis, pinnis 6–10 atrinque curvato-ascendentibus inferioribus, deltoideo-ovatis, 8 cm. longis, pinnula basali anteriore rachi incumbente, segmentis latissime cuneato-flabellatis, antice semicircularibus, 1 cm. latis, 8 mm. longis, papyraceo-firmulis, glauco-viridibus, antice profunde et creberrime aristato-serratis, dentibus deltoideis, dentibus usque ad ca. 24 numero. Nervis confertis flabellatis. Soris numerosis sed medio in margine segmenti solitariis rarissime binis i.e., partitis, usque ad 2 mm. longis 1.5 mm. latis, leviter curvatis nec sinu inclusis, indusio ochraceo firmo laevi.

HAB.—Rocks, W. Hupeh, Fang Hsien, 3000–4000 ft., November 1907, no. 2674.

Of the group of *A. venustum* Don, which is essentially Chinese (DIELS Fl. Central China **5**: 201. 1901), and which embraces half a score of species

related but perfectly distinct; two species extend beyond China, *A. venustum* of northern India and *A. monochlamys* Eaton of Japan. Our species is nearest to *A. Davidi* Franch., but differs in its larger dimensions, more rounded, monosorous pinnules, with numerous and aristate teeth.

Dryopteris pseudocuspidata H. Christ, n. sp.—Rhizomate repente, fere digiti minoris crassitie, brunneo, sublaevi, radicoso, stipite subsolitario, anguloso, 55 cm. longo, sublucido, dilute brunneo, pennae cygni crassitie, versus basin squamis ovatis obtusis brunneis deciduis sparso, planta caeterum laevi. Fronde 36 cm. longa 22 cm. lata, basi haud angustata, late ovato-deltoidea, acuminata, pinnata, pinnis ca. 18 utrinque, patentibus, 12 cm. longis 1.5 cm. latis lanceolato-acuminatis, vix petiolulatis, basi rotundato-truncatis, superioribus sensim diminutis nec adnatis, suprema petiolata valde diminuta. Pinnis dentatis, dentibus decumbentibus acutis interdum serrulatis. Costa manifesta prominente. Nervis ca. 40 utrinque, patentibus. Nervulis plerumque 6 utrinque, omnibus arcu acuto junctis. Soris minutis 6 utrinque medialibus brunneis, rotundis, separatis, exindusiatis. Textura papyracea, colore opaco, obscure viridi.

HAB.—W. Szech'uan, woodland, Mupin, 6000 ft., August 1908, no. 2603.

Habit of *D. cuspidata* (*Aspidium* Metten.) syn. *D. khasiana* C. Chr. Ind. 272, but belonging to the group *Nephrodium* with six lateral united veinlets.

PTERIS CRETICA L. var. **subserrulata** H. Christ, n. var.—A typo differt foliis papyraceis nec subcoriaceis dimorphis, fertilibus valde angustatis, sterilibus magis compositis, pinnis inferioribus basi bi- aut tripartitis, pinnulis lateralibus abbreviatis, rachi superiore late alata, marginibus acute et grosse biserratis.

HAB.—Shady rocks, Fang Hsien, 3000–5000 ft., July 1907, no. 2670.

In China *P. cretica* varies much and approaches *P. serrulata* L. fil. There are also forms of the latter species that approach *P. cretica* (Filic. Shen-si septentr. a P. J. GIRALDI lectae in Nuov. Giorn. Bot. Ital. IV. 1:6. 1897; *Pteris serrulata* var. *intermedia* Chr.), so that it is sometimes difficult to maintain a difference between the two species.

The starch of *Pteridium aquilinum* (L. Kuhn)

The specimen of starch from the rhizome of *Pteridium* from Ichang, below the famous gorge of the upper Yang-tze, Province Hupeh, that Mr. E. H. WILSON sent to Harvard University, con-

sists of compact angular fragments 1 cm. or more square, very white and pure, derived evidently from a layer precipitated in water. Professor SENN of Basel has kindly examined the specimen and I owe to him the accompanying drawings and the following description:

"The starch in question consists for the most part of combined grains. The grains joined in pairs have one side parabolically

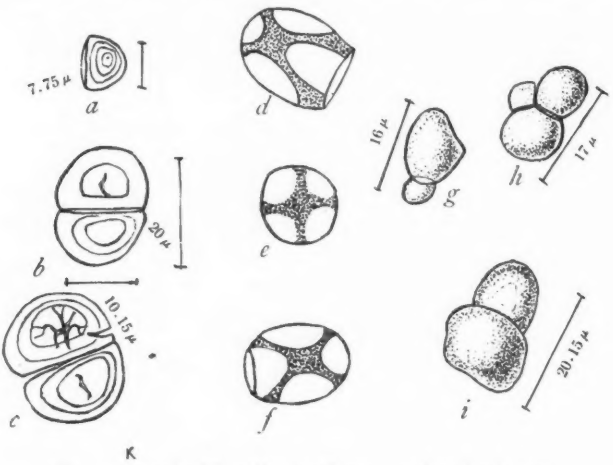

FIG. 2.—Starch of *Pteridium aquilinum:* explanation in text

rounded, while the side in contact is plane (fig. 2, *a–c*). Where there are several parts combined, they are placed sometimes one behind the other, sometimes one beside the other (fig. 2, *h*). The diameter of the grains vary from 3 to 18 μ; the average diameter is between 6.5 and 3 μ. The structure is slightly eccentric, depending on the arrangement by layers, which are not very evident except by examination with polarized light. The dark cross obtained by crossed Nicols is near the rounded end, and is seen especially in grains somewhat elongated (fig. 2, *d* and *f*). By a greater enlargement the nucleus of the layers can be observed (fig. 2, *a*). In the nearly globular grains the two dark striae cross in the middle (fig. 2, *e*). When the grains are submerged in water and under pressure of the cover glass, irregular cracks are seen,

which start often from the nucleus (fig. 2, *b* and *c*). The cause of these cracks is not the swelling but the pressure. In warm water the grains swell without cracks, and take the form of irregular linguiform corpuscles."

It is well known that the rhizomes of *Pteridium* have served on a large scale and still serve as food because of their richness in starch. In New Zealand and Australia they have been much used, and the natives of the Canary Islands make use of them also (C. BOLLE, Standorte der Farne auf den Canarischen Inseln, Zeitschrift für Allg. Erdkunde, Neue Folge xiv. 304). In 1884 I myself saw a peasant on the slope of Pic de Teneriffe dig up these rhizomes for this purpose. It is in the roasted and ground state that this root is used as food. According to HOOKER (Spec. Fil. ii. 199), Dr. B. CLARKE has written an article (Hook. Jour. Bot. **9**:212) recommending the use of this food. But the extraction of starch as the Chinese of Ichang practice it seems to be very rare. I find, however, a citation of LABILLARDIÈRE which says: "Amylacea radicum substantia, quam eliciunt mandendo, silvicolae Cap. V. Diemen sustentantur" (AGARDH Recens. spec. gen. Pteridis 1839, p. 46).

BASEL, SWITZERLAND

TWO EPIPHYTIC ALGAE

JULIA W. SNOW

(WITH PLATE XVIII)

Pirulus gemmata, nov. gen.

This minute alga was first found in 1897 growing in a culture with other small algae in the botanical laboratory at the University of Basel, Switzerland. Though the exact source of the culture cannot be stated, it is known to have come from the vicinity of Basel. The alga was next found in a culture taken from some epiphytic mosses and liverworts from Guatemala presented to the writer by Miss F. G. SMITH in January 1909. Though search has often been made for it in different parts of the United States, it has never been observed, and any record of its occurrence in the country has escaped notice by the writer.

In its early vegetative state the alga shows nothing distinctive and might easily be taken for a small *Chlorella* or the germinating zoospore of some higher form (fig. 1), but in the shape of the adult cell and in its mode of reproduction it stands unique among all green algae.

In shape the mature cell is pyriform, either perfectly symmetrical or somewhat irregular, 0.0084–0.0112 mm. in length and 0.0056–0.007 mm. at its greatest breadth (figs. 2, 3). The color is a very light green. The parietal chloroplast is cup-shaped, with the large opening either at one side or at the smaller end of the cell, so that a portion of the cell is always colorless. A large vacuole is present (fig. 5*a*). No starch was found in either the material from Switzerland or in that from Guatemala. In the former no reaction for cellulose was obtained with the chloriodide of zinc, but in the latter a distinct reaction was shown with that reagent. A further difference between the two forms was noted in the number of nuclei. In the Swiss material the mature cells when stained with hematoxylin showed four distinct nuclei, and in some instances eight were counted; while in the material from Guatemala a cell

showed but a single nucleus (fig. 5*b*). In all other respects, however, in the shape and the size of the cells, the nature of the chloroplasts, and mode of reproduction, but slight variations in the two forms occurred. The different results obtained in the membrane tests might possibly be explained by a difference in the reagents used, in which case the only real difference would lie in the number of the nuclei. As this is an internal difference rather than an external one, the two algae have been regarded as forms of the same species.

The most distinctive characteristic of this alga is its reproduction. Whereas all other similar forms multiply either by fission or internal division, producing either zoospores or non-motile gonidia, this form reproduces by budding. The smaller end of the pear-shaped cell elongates, then a slight constriction occurs near the end, and a membrane is put across, forming a cell which is nearly spherical, with a diameter much smaller than the original cell (figs. 3, 4). This new cell does not become detached immediately, but again the smaller end of the parent cell elongates and a second cell is produced between the original cell and the one last formed. This is repeated continuously, and often a chain of 12–14 cells is produced before the cells separate, the oldest of the series being farthest away from the original cell (fig. 6). Growth usually begins in each new cell as soon as formed, so that there is a slight increase in size from the youngest to the oldest of the chain, and often the largest ones of these begin to reproduce themselves before the breaking up of the filament takes place (figs. 7, 8). Instances were observed where new cells were seen to originate from opposite ends of the parent cell, but this was a rare occurrence.

The alga was cultivated in pure cultures under various conditions and in various concentrations of Knop's solution, but was found to vary little except in rapidity of growth and length of filament or chain formed. The greatest increase in the amount of material occurred in 0.2–0.5 per cent Knop's solution and on agar-agar plus 0.2 per cent of the same solution; while the longest chains of cells occurred in the weaker concentrations, such as 0.05 and 0.1 per cent, and on agar with a 0.2 per cent solution. With an increase in concentration there was a regular decrease in the

length of the chain of cells formed, until in 1 per cent rarely more than two cells were found united and growth was very meager. If cultures were old, whatever the concentration of the solution there was almost a complete separation of the cells, except once in a 0.4 per cent Knop's solution, where the plant floated on the surface of the liquid, long chains of cells were found. Even in the longest chain, however, the connection between the cells seemed to be a frail one, the cells becoming dissociated so easily that it is a question whether the alga should be called a unicellular one or a filamentous one. In this respect it resembles closely *Stichococcus*, which is classified by CHODAT (**1**) as a filamentous form, but which probably should be regarded as a unicellular alga.

In what condition this alga existed in its natural surroundings it is impossible to say, since it could not be observed on account of its minute size; but when first noted in culture, the scattered chains consisted of but two or three cells, and indicated that when it was put in the culture it was in the unicellular form.

The direct cause of this fragmentation of the chains or filaments was not determined, but the process resembled so closely a similar fragmentation observed by KLEBS (**3**) in *Hormidium nitens* that the cause is probably the same. KLEBS observed in his cultures of *Hormidium* that the fragmentation took place either in an insufficient amount of nutritive salts, or in absence of sufficient moisture, and offers a hypothetical explanation of the phenomenon. His theory is that under these conditions the alga at first ceases to divide and then ceases to grow, but that nutrition may continue for some time. As a result, the cell becomes filled with organic nutritive material, whereby the walls become distended and the layer of cuticula binding the cells together becomes broken and the cells fall apart. LIVINGSTON (**4**), however, in his work on *Stigeoclonium*, believed that a fragmentation occurred as a result of osmosis, and found that the higher the osmotic strength of the nutritive solution the more readily the dissociation of the cells took place.

The phenomenon of filaments falling apart into individual cells each of which continues to live, and under favorable condi-

tions to grow out into a long filament again, is characteristic of most epiphytic filamentous algae, such as *Stichococcus*, *Hormidium*, *Stigeoclonium*, and the following form, and in all cases, whether there is a specialized mode of reproduction or not, this phenomenon must be most instrumental in disseminating the plant. If in the dry epiphytic condition the plant exists in the unicellular state, as would seem to be the case, the cells must be easily blown from one locality to another, and so bring about a wide dissemination of the species. But during a rainy season, undoubtedly those single cells produce filaments which again become broken up into individual cells when the dry conditions return.

There is but little doubt that the alternating wet and dry conditions of the environment in which they live are the means by which the polymorphic conditions of these aerial forms are brought about. As they change their form according to conditions, assuming the nature of either a filamentous or a unicellular alga, they must be regarded as transitional forms between the unicellular and the multicellular genera, and as such they form a most interesting group.

Pirulus, nov. gen.—Alga unicellular, or forming short, fragile, beaded filaments. Mature cell pear-shaped, color a light green: chloroplast cup-shaped, with large opening at one side or at the smaller end; no pyrenoid present. Reproduction by budding, in which the smaller end elongates and is cut off by a membrane, after which a separation may occur or not.

Pirulus gemmata, nov. sp.—Mature cell 0.0084–0.0112 mm. long and 0.0056–0.007 mm. at broadest portion. Membrane of cellulose; a large vacuole at the center and a nucleus present (4 or 8 nuclei in European form). Often forming fragile filaments of 12–15 cells.

Found on epiphytic liverworts and mosses from Guatemala, also in Switzerland.

Aeronema polymorpha, nov. gen.

Growing constantly on mosses and liverworts in certain places, and occasionally on the surface of flower pots in plant houses, is a microscopic polymorphic alga, which, according to conditions,

may assume the characteristics of a typical unicellular alga, or may take on the nature of a well defined branched filament.

An alga which undoubtedly belongs in this same genus was found first in Basel, Switzerland, and its life history traced under the guidance of Professor KLEBS (**5**), but the species here given has been found in various places in the United States and under different conditions, but principally in the vicinity of Northampton, Massachusetts. In which phase of its polymorphism this alga existed in its natural habitat cannot with certainty be stated; its size is so minute, that its identity can be determined only in culture, and there the form that it assumes depends entirely on the cultural conditions.

In its filamentous state it resembles most closely *Conferva* and *Bumilleria* in that each cell contains several chloroplasts which have a peculiar light and transparent color, without starch and pyrenoid (figs. 10–14). The profuse branching of this form, however, would prevent its being classified with either of these genera, which are strictly unbranched. In its unicellular condition (fig. 15) it is doubtful if one could distinguish it from a small *Botrydiopsis*. The cells are spherical, with a number of light-colored, parietal chloroplasts, but the fact that it may assume a filamentous state would probably place it far from this form in the generally accepted system of classification.

In the filamentous state so profuse are its branches that it often forms relatively large, more or less spherical complexes in which the branches radiate from a common center with apical growth. In a vigorously growing culture (as in 0.03 per cent Knop's solution) the filaments are cylindrical, and in each cell there are relatively few irregular parietal chloroplasts (figs. 11, 12). Only a single nucleus is present, which sometimes may be seen between the chloroplasts without staining.

It has been found that the concentration of the culture medium exerts a great influence on the form the plant assumes. In a series of cultures made in different concentrations of Knop's solution ranging from 0.05 per cent up to 1 per cent, it was found that from 0.05 to 0.3 per cent there was a regular increase in individuals, also in the length and number of filaments, which

varied from 0.0028 to 0.006 mm. in diameter; while from 0.3 to 1 per cent reproduction decreased, and the length and number of filaments diminished. This reduction in length was accompanied also by a great increase in the diameter of the cells and the assumption of a spherical shape, followed by an almost complete fragmentation of the filaments previously formed (fig. 15). The diameter of these cells reached as much as 0.0228–0.028 mm. In this condition a well defined reaction for cellulose was obtained in the membrane with the chloriodide of zinc, but this was not obtained in the filamentous stage. In some cases a strand of protoplasm was seen to extend from each chloroplast toward the center; this probably extended to the nucleus, though it could not be determined definitely.

The alga reproduces by means of zoospores 0.005–0.0065 mm. long and 0.0018–0.003 mm. broad (fig. 18). They are pointed at both ends, have a single chloroplast, a single cilium, and a pigment spot. They are very amoeboid in their motion, bending back and forth, and changing their shape from time to time. After a period of activity they come to rest, assume a spherical form, and germinate immediately. The zoospores are formed by the successive division of the contents of a mother cell into 2, then into 4, 8, 16, or many segments (fig. 17). Usually there are 16 or 32 from each cell. They may be formed from any cell, but they seem to be formed first in the central cells of a complex rather than in the ends of the filaments. They are liberated by the gelatinification of the whole membrane and its expansion by the motion of the zoospores until one by one the zoospores become liberated and swim away. Often the process is very slow.

In respect to the zoospores, as well as to the vegetative structure, the resemblance to *Conferva* and *Botrydiopsis* is manifested, as all three have amoeboid zoospores with a single cilium; a difference, however, lies in the fact that these zoospores have only one chloroplast, while the others have two.

The mode of germination of these zoospores and the development into filaments seem to be the same as occurs in the genus *Stigeoclonium*. Soon after a spore comes to rest (fig. 19), it divides into two, and then into a chain of four, the two outer

cells developing in opposite directions into filaments, while the two central cells protrude laterally and give rise to two more filaments (figs. 10–12). Any cell of any of these filaments seems capable of producing a branch, and by the continued growth and branching the large complexes are formed, radiating from the two original cells at the center. Early in their history, however, division occurs in these cells in all three directions of space, so that a parenchymatous mass is formed, from which the branches radiate (figs. 13, 14). CIENKOWSKI (**2**), in writing of *Stigeoclonium*, refers to a similar structure from which the branches radiate, and calls it a *sole*.

As the age of a culture increases, especially in cultures of high concentration, the tendency toward the formation of these parenchymatous masses increases until we find large solid structures with but little resemblance to a filamentous alga (fig. 16).

It has long been known that in the Conjugatae certain forms of desmids resemble closely a single cell of corresponding filamentous forms, as, for example, *Spirotaenia* and *Spirogyra; Cylindrocystis* and *Zygnema; Mesotaenium* and *Mougeotia*. A like similarity must be taken into account in the case of *Conferva* and *Botrydiopsis*, as the nature of the individual cells and the reproduction are almost identical. In this new genus it would seem that we have a transitional form between the well defined filament of *Conferva* on one side and the unicellular *Botrydiopsis* on the other. Or possibly *Conferva* might be an intermediate form between this and *Botrydiopsis*, as certainly the branched nature would indicate a higher development than the single filament. But the filament of *Conferva* is less fragile than the filament of this form, so it is difficult to say what would be the most correct classification.

LUTHER (**5**) and WEST (**6**) would place all algae characterized by the distinctive light green shade shown in this form into one class, the HETEROKONTAE, irrespective of their shape, size, filamentous or unicellular nature; but whether one accepts the views of these writers or retains the older classification, the genus *Aeronema* must be placed near to *Conferva* or *Bumilleria*.

Aeronema, nov. gen.—Microscopic branched filamentous alga, filaments according to conditions often becoming beaded and fragmented or forming more or less parenchymatous masses. Chloroplasts several or many in each cell; light in color, without pyrenoid. Reproduction by means of amoeboid zoospores with a single flagellum, a single chloroplast, and a pigment spot.

Found in Switzerland and the United States.

Aeronema polymorpha, nov. sp.—Diameter of filaments 0.0028–0.006 mm. No starch or oil present; membrane (in beaded filaments) of cellulose; 16 or more zoospores formed in a cell, each 0.005–0.0065 mm. long and 0.0018–0.003 mm. broad.

Found in Massachusetts.

The writer wishes here to express her thanks to Miss F. G. SMITH for material brought from Guatemala, and to Professor G. KLEBS for guidance and inspiration in the original study of these genera.

SMITH COLLEGE
NORTHAMPTON, MASS.

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6. WEST, G. S., A treatise on the British freshwater algae. Cambridge. 1904.

EXPLANATION OF PLATE XVIII

All drawings except fig. 16 were made with a Zeiss 3 mm. objective and no. 6 ocular. Fig. 16 was made with a Zeiss 8 mm. objective and no. 6 ocular. An Abbé camera lucida was used in all drawings except in fig. 18, when two of the zoospores were drawn free hand.

Pirulus gemmata, nov. gen.

FIG. 1.—Young cells.
FIG. 2.—Mature cells.

FIG. 3.—Mature cells somewhat irregular because of crowding.

FIG. 4.—Different stages in the formation of filaments.

FIG. 5.—Optical section showing vacuole (*a*) and nucleus (*e*).

FIG. 6.—Mature filaments.

FIGS. 7, 8.—Filaments showing cells reproducing before dissociation.

Aeronema polymorpha, nov. gen.

FIGS. 9–12.—Young filaments.

FIGS. 13, 14.—Older individuals taken from a culture in 0.3 per cent Knop's solution.

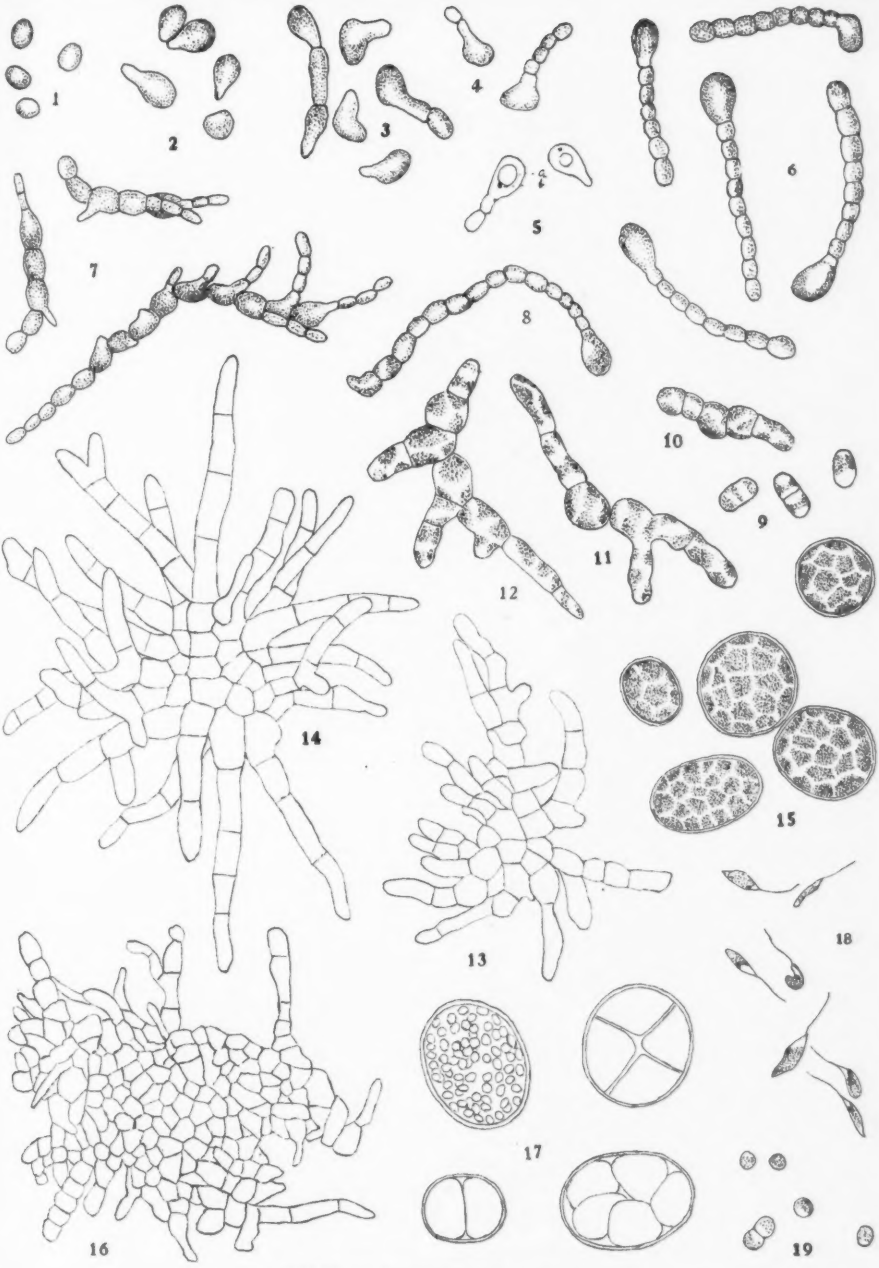
FIG. 15.—Unicellular condition taken from an old culture in 0.3 per cent Knop's solution.

FIG. 16.—Parenchymatous mass taken from an old culture in 0.05 per cent Knop's solution.

FIG. 17.—Different stages in the formation of zoospores from the unicellular condition.

FIG. 18.—Zoospores.

FIG. 19.—Germinating zoospores.



SNOW on EPIPHYTIC ALGAE

THE DEVELOPMENT OF THE SPORES IN PLEURAGE ZYGOSPORA

I. M. LEWIS

(WITH PLATE XIX)

Pleurage zygospora (Speg.) Kuntze, formerly reported from Italy alone, has been shown by the cultural methods employed by THAXTER and later by GRIFFITHS[1] to occur throughout this country. This species was first described by SPEGAZZINI[2] in 1878, and was placed in *Sordaria* as *S. zygospora*. It was later transferred from this genus by SACCARDO[3] and placed in *Philocopra*. This transfer was made on the basis of the apparent number of spores being 16 in place of 8. Later (1898) KUNTZE[4] described it as a *Pleurage*. This classification was retained by GRIFFITHS in his memoir. The species name *zygospora* has been retained throughout.

The position of this species depends upon the interpretation which is placed upon the mature ascospore. It is obvious that such an interpretation should be based upon a knowledge of the development of the spore. A cytological study of the peculiar appendaged condition of the spores in the genus *Pleurage* has not, so far as the writer is aware, been carefully made. A complete understanding of the nature of the primary appendages necessarily involves a study of the behavior of the nucleus of the primary sporogenous cell. This detail was not attempted by GRIFFITHS in his memoir on the Sordariaceae.

The spores of the species of this genus in which the primary appendage occurs are known to pass through a peculiar mode of development. The primary sporogenous cell is cut out of the cytoplasm of the ascus after the method described by HARPER.[5] These

[1] GRIFFITHS, D. A., The North American Sordariaceae. Mem. Torr. Bot. Club 11:1–134. 1901.

[2] SPEGAZZINI, C., Michelia 1:227. 1878.

[3] SACCARDO, P. A., Sylloge Fungorum 1:251. 1882.

[4] KUNTZE, OTTO, Revisio Generum Plantarum 3:505. 1898.

[5] HARPER, R. A., Annals of Botany 13:507. 1899.

cells are quite small, cylindrical, hyaline, straight or curved, and do not differ markedly in structure from the abundant epiplasm of the young ascus. They grow for a time and become transformed into filamentous cells, the length of which varies in different species. When one of these cells approximates its maximum length, the upper end begins to enlarge and forms an ellipsoid portion into which the greater part of the protoplasm migrates. This portion then becomes cut off by a cross-wall and forms the fertile cell of the spore. The remainder constitutes the so-called primary appendage. *Pleurage zygospora* shows upon a superficial examination that the spores are developed after this same general method.

Because of the peculiar interest attaching to this method of spore-formation, and also because of the great variability found to obtain in spores of *Pleurage zygospora* from collections made in the vicinity of Austin, Texas, the writer deemed it desirable to make a detailed cytological study of their complete development. The material for this study was grown in damp chambers on the natural substratum, and was prepared according to the methods employed in modern cytological technique. Flemming's solution, weaker formula, as a fixing agent left nothing to be desired. The best stain was found to be the Flemming triple stain. Sections 10 μ thick gave very good preparations for study.

The immature perithecia contain many different stages in the development of the ascus, so that the stages could be studied in unbroken continuity in any one section. The study of fixed and stained material was supplemented by the use of fresh material crushed in water on the slide, and then treated with dilute aqueous gentian violet or eosin glycerin.

The details of nuclear division in the ascus and the young spore were not studied critically, as it did not appear that the material was favorable for a determination of the phenomena of chromosome reduction. The primary nucleus of the young ascus is quite large, and the chromatin material appears to be divided into four parts, but spindle stages were not observed (figs. 1–3). The cytoplasm is quite vacuolate, and this condition increases with the rapid enlargement of the ascus (fig. 4). After the ascus reaches about one-half its mature size, the division of the primary nucleus

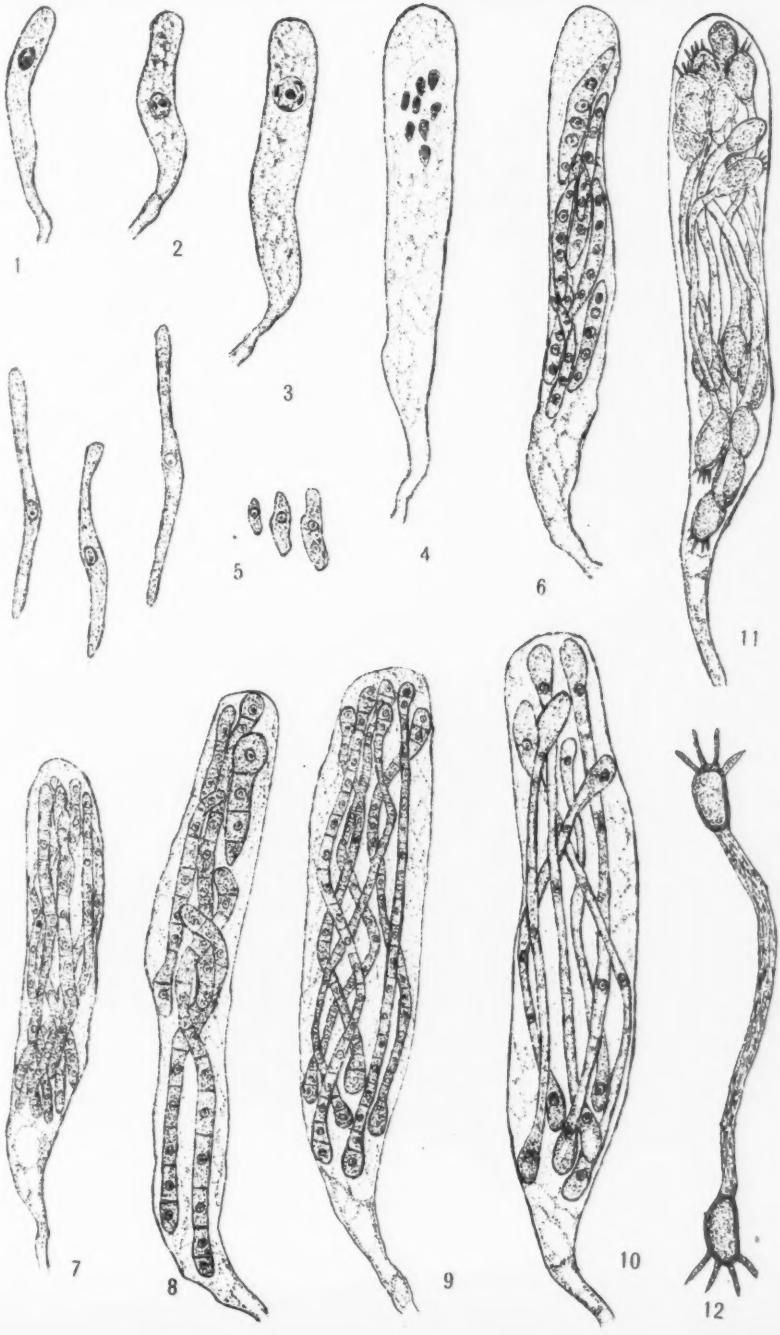
takes place, and this is followed quickly by two succeeding divisions, so that 8 cells are formed in the ascus in the usual way. These cells lie quite close together near the upper end of the ascus, are very small, and there is an abundant epiplasm (fig. 4). These are the primary sporogenous cells which later give rise to the fertile cells of the spores. They are cylindrical, hyaline, and the cytoplasm is more dense than the epiplasm surrounding them. The ascus has not at this time reached its mature size, and the spores appear as very minute cells in its upper end (fig. 4).

Further development from the primary cells was found to be quite variable in any one perithecium. In all cases, however, the sporogenous cell begins to elongate and to enlarge in all directions. It most frequently happens that the growth takes place faster on one side than on the other, so that the cell becomes somewhat crescentic in shape. It is also slightly bulged out near its middle (figs. 5, 6). It often happens that the nucleus of the young spore divides before the cell has grown to more than two or three times its original length (fig. 5), but this is by no means always the case. Frequently the nucleus remains undivided even after the cell has reached the length equal to half that of the ascus. In a few cases it was observed that the nucleus did not divide at all. As the cell elongates, its cytoplasm becomes vacuolate and more resembles the epiplasm from which it is derived. The nucleus usually divides, and after the daughter nuclei have moved apart, succeeding divisions take place until a number of free nuclei are present in the spore (figs. 6–10). The filamentous cell grows in length until in many cases it becomes longer than the ascus, and is consequently compelled to assume a spiral position. It is at this time almost uniform in diameter throughout its length, and the nuclei are distributed along the entire filament. The cytoplasm contains many vacuoles and the epiplasm is greatly reduced. The formation of cross-walls may or may not take place. Both types of asci occur in the same perithecium, but one type usually predominates in any one perithecium. In the cross-walled type the walls are usually formed at about the stage shown in fig. 6. Stages such as shown in figs. 10 and 11 never form cross-walls. In some perithecia there may be only a single ascus of the cross-walled type, while in others

this type predominates. In no instance has an ascus been observed in which both types occur. In all of the multicellular filaments, each cell has a nucleus, and the cytoplasm is apparently more dense than in the other type.

About the time the filament has reached its maximum length or slightly earlier, the two ends begin to enlarge, and the cytoplasm in these ellipsoid portions becomes very dense. Each end portion usually contains a single nucleus (fig. 10). No cases were observed in which two nuclei were present, but occasionally it appears that a nucleus does not migrate to the end of the filament, and in such cases the end portion becomes abortive. In the case of the multicellular type, the end portion which is enlarged may consist of a single cell or of two or more cells (figs. 8, 9). These enlarged end portions become the fertile cells of the spore, and at maturity are about 15–20×25–40 μ in size. The connecting filament is homologous in origin with the primary appendage of other species of the genus. This primary appendage is seen to connect the two fertile portions of a single spore in this species. Each of these fertile portions functions as a spore. The primary connecting filament persists for some time, but at the maturity of the perithecium and the shedding of the spores, it has almost disappeared, thus separating the two portions, and the ascus produces, therefore, the functional equivalent of 16 spores. The primary appendage in this species is either one multinucleate cell or a filament made up of a number of cells. In some cases the multicellular spores were observed to present a somewhat abortive appearance (fig. 8), in which case it happens that one fertile cell only is produced. Abortion is not uncommon in the other type of spore, so that often only five or six pairs of fertile cells are produced, or sometimes the number of fertile cells is different in the two ends of the ascus.

The question quite naturally arises as to the definition of a spore, and whether this species produces 8 or 16 spores. It was on this basis that SACCARDO transferred the species to *Philocopra*. Functionally 16 spores are produced, but morphologically there are only 8. These 8 spores are either three-celled, that is, two fertile cells connected by a long multinucleate cell (fig. 10), or they may be multicellular, consisting of two fertile parts connected by



LEWIS on SPORES of PLEURAGE

a long multicellular sterile portion which eventually disappears. The basis of the structure and origin of the spores seems to me to be the proper basis for their definition. I regard this species, therefore, as eight-spored, and the classification of KUNTZE as the proper one.

The question concerning the probable significance of the two types of spores produced, while interesting, must remain more or less speculative. It seems probable that this condition must have been derived from ancestors which produced multicellular spores, and that the production of fertile and sterile cells is due to specialization and sterilization. The first step in this process might have consisted in the formation of the enlarged fertile cells, following which the connecting cells ceased to be functional. The loss of cross-walls and the consequent production of the unicellular appendaged type of spore, characteristic of this and other members of the Sordariaceae, could easily follow.

UNIVERSITY OF TEXAS
AUSTIN

EXPLANATION OF PLATE XIX

All figures were drawn from sections with the aid of a camera lucida, a Leitz $\frac{1}{12}$ oil immersion lens, and ocular no. 1, and are magnified 880 times.

FIGS. 1–3.—Young asci showing relatively large nuclei and rather dense cytoplasm.

FIG. 4.—Ascus about two-thirds mature size, with vacuolate epiplasm and 8 primary sporogenous cells.

FIG. 5—Various stages in the growth of the spore filament.

FIG. 6.—Young spores showing the crescentic shape and with several nuclei; the ascus has not increased much in size.

FIG. 7.—Spore filaments of the cross-walled type; the spores are almost as long as the ascus, but the end portions have not begun to increase in size; this same appearance prevails in the other type of spores.

FIG. 8.—A later stage than fig. 7; some of the spores are abortive, a condition which frequently occurs.

FIG. 9.—Older stage of the same type of spore shown in fig. 8, with the ends becoming enlarged.

FIG. 10.—The unicellular type, showing the multinucleate condition and enlarged ends, each containing a single nucleus.

FIG. 11.—Mature spores of the type shown in fig. 10; secondary appendages derived from the epiplasm are shown.

FIG. 12.—Mature spore of the three-celled type.

NOTES ON GINKGO BILOBA[1]

WALTER W. TUPPER

(WITH PLATE XX)

Among the gymnosperms, one of the groups most interesting from a morphological standpoint is the Ginkgoales, the only living representative of which is *Ginkgo biloba*, or maidenhair tree of China and Japan. This group is of special importance and value to the morphologist because of the close resemblance which its reproductive characters bear to those of the Archigymnospermae, and the many ways in which its vegetative anatomy resembles that of the lower conifers. Thus, the modern *Ginkgo biloba* forms the connecting link between the lower conifers and the Archigymnospermae. The presence of well-marked annual rings, and of opposite pits with bars of Sanio on the tracheids, and the absence of either terminal or diffuse xylem parenchyma in the branch of *Ginkgo* are some of its characters which show its close relationship with the pinelike or lower conifers.

During this last year, the writer has made some studies of the wood and short shoots of *Ginkgo*. Perhaps the most striking characteristic of the anatomy of the wood is the presence and distribution of crystal cells and wood parenchyma. SEWARD and GOWAN[2] say that in a fairly old root the medullary rays contain a few crystal sacs, and that the wood parenchyma also includes some crystal-containing cells. Nowhere in their paper do they refer to the peculiar arrangement of the xylem parenchyma, nor is it shown by any of their plates. In another part of this same paper they describe the occurrence of swollen parenchymatous cells, full of crystals, in the secondary bast, cortex, pith, and medullary ray tissues. Nothing peculiar, however, is noted regarding

[1] Contributions from the Phanerogamic Laboratories of Harvard University, no. 34.

[2] SEWARD, A. C., and GOWAN, MISS J., The maidenhair tree (*Ginkgo biloba* L.). Annals of Botany **14**:135. 1900.

their distribution. PENHALLOW,[3] GOPPERT,[4] and others have described the existence of crystal cells, or idioblasts, in the branch of *Ginkgo*, and PENHALLOW has even added that they occur scattered throughout the wood and often in vertical series.

From a careful examination of the root, I have found that these idioblasts, or crystal-containing cells, and parenchyma cells invariably occur in longitudinal rows, or series, which run from ray to ray. In every single case these parenchyma and crystal cells were found in relation with a ray, as is shown in figs. 1, 2, and 3.

Fig. 1 is a radial section of the wood of the root, and shows the large, round, crystal cells, or idioblasts, in a longitudinal row connecting two rays. To the side of and intermingled with the crystal cells of this row are parenchyma cells, some of which appear as appendages of the rays. These parenchyma cells apparently give rise to the crystal cells, or else are modified into them. Some of the crystal cells are torn, due to the fact that the crystals of calcium oxalate which they contained were not fully dissolved by treating with hydrofluoric acid. The crystal cells are seen in contact with a ray in a tangential view in fig. 3.

The Ginkgoales are the connecting link between the Archi- and Metagymnospermae, possessing, as they do, motile sperm cells and other reproductive characters of the Archigymnospermae, together with anatomical characteristics of the Metagymnospermae, such as clearly marked annual rings, bars of Sanio, opposite pits on their tracheids, and only vestigial traces of centripetal wood (in their foliar organs). The wood parenchyma, however, is related to the rays, and extends in *radial* rows, unlike the *tangentially* distributed wood parenchyma found in the conifers. Wood parenchyma, like annual rings, appears to have been produced by woody plants as a reaction to the arrival of winter conditions in the geological and climatic evolution of the earth. Figs. 2 and 4, the former a radial, the latter a transverse section of the *Ginkgo* root, also show the peculiar distribution of the xylem parenchyma and crystal cells.

Like the Pineae, probably the oldest conifers, *Ginkgo* has its

[3] PENHALLOW, D. P., A manual of the North American gymnosperms. p. 209. 1907.

[4] GOPPERT, H. R., Monographie der Fossilen Coniferen. p. 266. 1850.

leaves borne on short shoots. One of the nost noticeable things about the short shoots of *Ginkgo* is the fact that quite frequently they branch within the wood of the limb out of which they grow. In fig. 5 we have a transverse section of a branching short shoot, showing the two divisions entirely separate from each other, yet still within the wood of the branch. Fig. 6 shows this same branching short shoot sectioned nearer the pith, with the short shoot not yet divided.

SEWARD and GOWAN (*l.c.* p. 132) say that in some instances the short shoot of *Ginkgo* may branch like the trunks of *Cycas*. To illustrate this they have reproduced a natural-sized cut (*l.c.* pl. 9, fig. 42) of a branching short shoot. The branching to which they refer, however, takes place entirely outside of the wood of the limb, as is shown by their figures.

It is of special interest in this connection to note that a new araucarian conifer, *Woodworthia*, from the Triassic of the Fossil Forest of Arizona, which has been examined and described by Professor JEFFREY[5] has short shoots which likewise divide within the wood of the branch. This gives us convincing evidence that the araucarian conifers are an old group, and have possibly come from the same stock as the Ginkgoales. Unlike the short shoots of *Ginkgo*, those of the araucarian conifer mentioned apparently never grew out into long shoots.

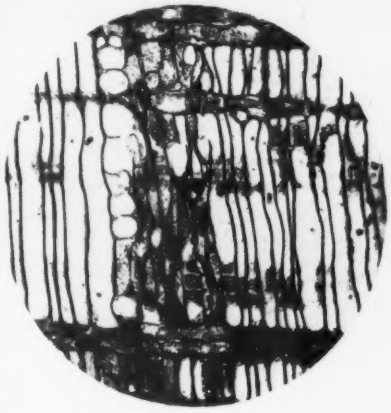
Like the Ginkgoales and araucarian conifers, the older Abietineae likewise had short shoots. It would be interesting, were the material available, to examine the short shoots and woody branches of *Prepinus*, the probable ancestor of the Abietineae, in search for branching within the wood of the limb.

Summary

The root of *Ginkgo biloba* contains crystal cells and wood parenchyma distributed in rows or series which run longitudinally throughout the root in radial planes.

All of these rows of cells are in contact with at least one ray. In some places the wood parenchyma cells can be distinguished

[5] JEFFREY, E. C., Proc. Boston Soc. Nat. Hist. **34**: *pls. 31, 32.* 1910.



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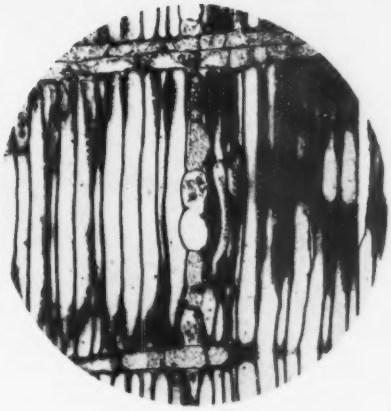

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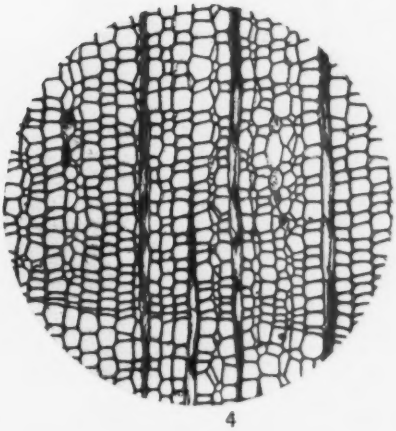

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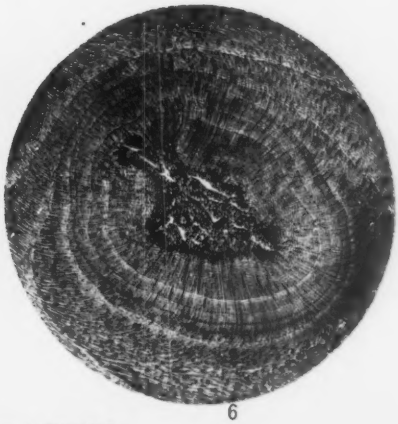

6

TUPPER on GINKGO

as appendages of the rays. The crystal-containing cells seem to be a modification of the parenchyma cells.

The fact that all of the xylem parenchyma found in *Ginkgo* is very differently distributed from that found in the conifers (radial and not tangential) suggests that it is a primitive type.

The short shoots of *Ginkgo* frequently divide within the wood of the branch. The only one of the conifers which is known to have such a peculiarity is the new araucarian genus *Woodworthia*.

This work has been done in the Phanerogamic Laboratories of Harvard University. The writer is indebted to Professor JEFFREY for advice and guidance throughout the investigation, and for aid in securing the accompanying photomicrographs.

HARVARD UNIVERSITY

EXPLANATION OF PLATE XX

Ginkgo biloba

FIG. 1.—Radial section of root, showing crystal-containing cells in contact with a ray, and distributed in a row (intermingled with parenchyma cells) which runs longitudinally along the root; parenchyma growing out from rays; ×80.

FIG. 2.—Radial section of root, showing two rays connected by a row of crystal cells; ×80.

FIG. 3.—Tangential section of root; ×80.

FIG. 4.—Transverse section of root; ×80.

FIG. 5.—Transverse section of branching short shoot, showing the divisions entirely separate from each other, yet still within the wood of the branch; ×12.

FIG. 6.—Transverse section of branching short shoot seen in fig. 5, sectioned nearer in toward the pith of the branch, showing the short shoot undivided; ×12.

THE ORIGIN OF THE CHLOROPLASTS IN THE COTYLEDONS OF HELIANTHUS ANNUUS

EDWIN C. MILLER

(WITH PLATE XXI)

There are two prevalent opinions in regard to the origin of chloroplasts in seedlings. One group of investigators holds the view that the chloroplasts originate directly from the cytoplasm of the cell. According to them, the mature seed from which the seedling originates contains no chloroplasts. They hold that if any chloroplasts are present in the young embryo, they lose their color and disintegrate at the ripening of the seed, and that at germination the protoplasm in the cells of the cotyledons gives rise to new chloroplasts which function during the period of activity of these organs. The other group of investigators maintains that the protoplasm of the cell never gives rise to chloroplasts, but that the fertilized egg contains chromatophores which have been derived directly from the parent plant. During the development of the egg into the embryo these chromatophores multiply, and in this manner provide every cell of the embryo with chromatophores. In many seeds before maturity the chromatophores have become differentiated into chloroplasts, which are plainly visible. During the ripening of these seeds their chloroplasts lose their color and shrivel up, and on this account they are difficult to detect in the mature seed. At germination, however, the chloroplasts again become active and assume their original form and color.

SACHS (1) states that the chloroplasts arise in the young cells by the separation of the protoplasm into portions which remain colorless and others which become green and sharply defined. He holds that the process can take place by very small particles, originally of a different nature from the apparently homogeneous protoplasm in which they are distributed, collecting at definite places and appearing as separate masses.

MIKOSCH (**2**), after an examination of the seeds and seedlings of *Helianthus annuus*, reached the conclusion that there are no chromatophores present in the resting seeds of this plant, but that during germination the chloroplasts arise directly from the protoplasm of the cells. He holds that their origin is due to the condensation of the cell plasma in definite places. This condensation he thinks is probably brought about by a loss of water in those parts. The condensed parts soon take on the green color and become the chloroplasts. This process of formation goes on independently of light. The bodies thus formed are at first rod or spindle-shaped, but later assume the typical disk shape of the choloroplasts.

BELZUNG (**3**), after a lengthy investigation of the ripening seeds as well as of the mature seeds and seedlings of many plants, came to the following conclusions: (1) that the free growth of starch grains can take place without the intervention of leucoplasts; (2) that the chloroplasts are formed directly by a differentiation of the protoplasm; (3) that the chloroplasts can also be formed at the expense of the starch grains which have their origin in the cytoplasm of the cell. The severe criticism of his work by SCHIMPER (**4**) led BELZUNG to traverse anew his previous work, and in a paper published in 1891 (**5**) he verified his previous conclusions. In this investigation he used as material *Phaseolus vulgaris*, *Lupinus albus*, *Lupinus elegans*, *Faba vulgaris*, *Pisum sativum*, and other plants. According to his observations, the young embryo contains no chloroplasts. The starch grains formed in the young embryo are laid down in the vacuoles of the protoplasm. He holds that those who claim that starch grains are the product of leucoplasts are in error, and that the leucoplasts defined by different investigators are simply the boundaries of the vacuoles in the protoplasm. The green color of the embryo in many plants is due to a green pigment distributed throughout the protoplasm of the cell. According to BELZUNG, therefore, there are no chromatophores present in the embryo, and consequently none in the mature seeds. At germination the simple starch grains of the seed disintegrate, and numerous compound grains of transitory starch appear in various parts of the protoplasm. These com-

pound grains are formed as follows. Each large vacuole is composed of two to five secondary ones. In each of the latter a small starch grain is formed, the several grains making the compound grain. As this grain disappears, an infiltration of the green pigment takes place and thus a chloroplast is formed. BELZUNG made most of his observations upon fresh material and used iodine green for his staining.

MEYER (**6**), after his thorough investigation of the structure and nature of the chloroplasts, reached the conclusion that the origin of the chromatophores does not take place in the young plant cells, but that they are derived from other cells in which they previously existed, and that they increase in number by the division of those already present.

SCHIMPER (**7**) found chromatophores present in the embryo sac and egg of numerous phanerogams. Although his observations were rather meager, he concluded that the chloroplasts thus present in the young embryo were not reabsorbed in the ripening seed, but that they merely become colorless and lose their function. Upon germination, after they have again taken on the green color, they become functional.

BREDOW (**8**) examined a large number of green, yellowish, and colorless seeds, and came to the conclusion that chloroplasts were present in all of them, although they stain very poorly and are hard to detect. He studied the seeds of *Pisum sativum*, *Robinia Pseudacacia*, *Cucurbita Pepo*, *Acer crataegifolium*, *Ipomoea splendens*, *Pinus austriaca*, and *Lupinus luteus*, both in the fresh condition and after the treatment with reagents. The sections of the fresh seeds were mounted in cell sap or in weak glycerin. Good results in staining the chloroplasts were obtained by treating the sections for several days with a concentrated solution of picric acid. This colored all the proteid material yellow, but the chloroplasts showed a deeper stain than the other cell contents. In sections treated with picric acid, washed with water, and then stained with hematoxylin, the chloroplasts also showed well. BREDOW found that the chloroplasts of the seed increased during germination by simple fission, and also by a division of one chloroplast into as many as ten or twelve smaller ones by numerous irregular

divisions. He believed that the greening of these numerous small bodies led the earlier investigators to the conclusion that the chloroplast originates directly from the protoplasm of the cells of the seedling. It is worthy of note that BREDOW worked with *Lupinus luteus*, a seed in which BELZUNG found no chloroplasts at all.

FAMINTZIN (**9**) investigated the origin of chloroplasts in seedlings, and especially the manner in which the chloroplasts, if present in the seed, divide. He selected as his material for investigation the seeds and seedlings of the sunflower, using the fresh material of seeds and of 16 and 24-hour seedlings. By ZIMMERMAN'S method he was unable to distinguish the small aleurone grains and particles of proteid from the chloroplasts, since the whole cell content stained red. He then originated a modification of this method by treating the sections previous to fixing and staining with acetic acid. The sections were left in 1 per cent acetic acid for 24 hours, or less for a stronger solution of the acid, and were then fixed and stained according to the method of ZIMMERMAN. By this means the protein granules and grains remained colorless or were only faintly colored red, while the chloroplasts and other protoplasmic structures were stained a deep red. In this way FAMINTZIN was able to make out the chloroplasts in the resting seed and during the early stages of the germination. Some of the chloroplasts in the resting seed are in the cytoplasm lining the cell wall, but by far the greater part of them, according to him, are in the film of protoplasm which surrounds the protein grains. Upon placing fresh sections of the material in the light, he observed that these small bodies on the protein grains took on a yellowish or brownish color. By identifying these bodies in the young stages of the seedlings, FAMINTZIN concluded that the seeds of the sunflower contain chloroplasts, and that these by simple fission give rise to those of the seedling.

The seeds for the following investigation were planted in white quartz sand and placed in the greenhouse at a temperature of 65–75° F. At intervals of 12 hours the seedlings were taken up, and parts of the cotyledons near the middle were placed in the fixing material. This was carried on until the plants were above

the ground and had become true photosynthetic structures. The seedlings were examined at 11 different stages exclusive of the seed. Chromacetic acid solution was used for fixing, and the material was washed, dehydrated, and imbedded in paraffin in the usual manner. Various methods of staining were tried. By the use of ZIMMERMAN'S method the same difficulties were encountered as were experienced by FAMINTZIN. In the later stages of the seedlings the chloroplasts are plainly differentiated, but during the early stages they could not be distinguished at all from the protein granules in the cell. Sections which had been treated with picric acid and then tinged with eosin also showed the chloroplasts plainly in the later stages of the seedling, but during the earlier stages the protein matter, as well as the chloroplasts, takes a deep stain and the identity of the latter is uncertain. Sections were then treated according to FAMINTZIN'S modification of ZIMMERMAN'S method. One series of sections was placed in 30 per cent acetic acid for 30 minutes, then washed with running water and transferred to 0.2 per cent acid fuchsin. After being allowed to stand for 24 hours in this solution, the sections were washed in running water for 12 hours, dehydrated in 95 per cent and absolute alcohol, cleared in xylol, and mounted in balsam. Another series of sections was treated in the same manner, except that they were left in the 30 per cent acetic acid 45 minutes. The results obtained from the last series were the most satisfactory, and the examination of the material was made upon these sections.

The sections first examined were those of seedlings which were fully developed, and the number and position of the chloroplasts in the cell were clearly evident (fig. 12). Those next examined were of seedlings 12 hours younger, and fig. 11 shows the usual position of the chloroplasts at this stage. This method was continued step by step back to the original seed, since obviously the best means to find the nature of the origin of the chloroplasts is to trace them backward in this manner from stages in which there can be no doubt at all as to their position and identity. The chloroplasts, as shown clearly in figs. 1–12, occupy the normal position in the cytoplasm of the cell at all stages of the development of the seedling. In the resting seed, according to our opinion,

they are present in their usual place but are very minute. As the seed begins to germinate, they increase in size and then begin to divide by simple fission. The chloroplasts of the seed are thus the bodies which give rise to the chloroplasts of the mature seedling. The numerous small round bodies which are on the surface of the protein grains, and which take the red stain after the same manner as the chloroplasts, we do not consider as chloroplasts, since in the first place they are entirely too numerous to correspond with the number of chloroplasts in cells where their identity cannot be doubted, while the number of chloroplasts found in their normal position closely corresponds to the number which is found in the later stages of development. Also, these small bodies are plainly evident upon the protein granules in advanced stages of germination, when there is not the least doubt as to the identity of the chloroplasts. We agree with FAMINTZIN that the chloroplasts are present in the resting seeds of *Helianthus annuus*, and that they alone give rise to those of the seedling. We think, however, that he is in error in considering the small bodies which cover the protein granules as chloroplasts. What these bodies are we are unable to tell, but it seems evident that the stained bodies observed in the natural position of the chloroplasts account for all which appear in the seedling.

In conclusion I desire to extend my sincere thanks to Professor A. W. EVANS, at whose suggestion the work was undertaken, for his able advice and criticism; also to Dr. GEORGE E. NICHOLS, who gave me valuable advice in the preparation of material.

YALE UNIVERSITY

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EXPLANATION OF PLATE XXI

The abbreviations used are as follows: *c*, chloroplast; *l*, protoplasm; *p*, protein grains; *pf*, protein grain with bodies designated as chloroplasts by FAMINTZIN; *dp*, protein grains beginning to disintegrate; *n*, nucleus; *pl*, protoplasm and disintegrated protein grains; *v*, vacuole.

FIG. 1.—A lower palisade cell from a cotyledon of the resting seed; the protein reserve is seen in the form of large grains (*p*); the chloroplasts are seen in their usual position near to the cell wall; seven chloroplasts are visible in this section; ×600.

FIG. 2.—A palisade cell from the cotyledon of a seed 12 hours after planting; the protein grains are still intact; the protoplasm has become vacuolated and active; at either end of the section of the cell the chloroplasts are seen; ×600.

FIG. 3.—A palisade cell from the cotyledon of a seed 24 hours after planting; the protoplasm has become dense and shows no definite structure; the chloroplasts are still small; ×600.

FIG. 4.—A cell from the palisade layer of the cotyledon of the seed 36 hours after planting; the chloroplasts (*c*) have increased in size; the rudimentary hypocotyl and root of the seed have not yet penetrated the seed coats; ×600.

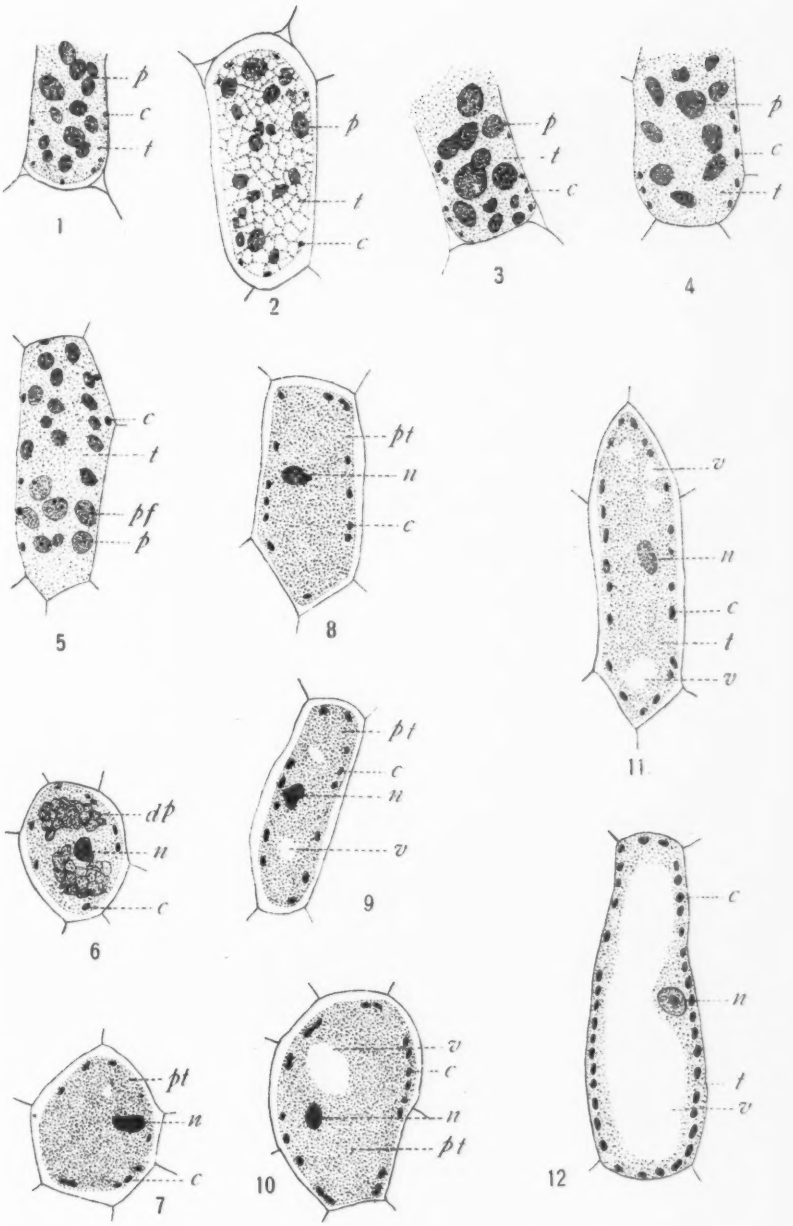
FIG. 5.—A palisade cell 48 hours after the planting of the seed; on the protein granules (*pf*) may be seen the bodies designated by FAMINTZIN as chloroplasts; the hypocotyls in the seedlings have a length of 0.6 cm.; ×600.

FIG. 6.—A cell from the spongy layer of a cotyledon in a 60-hour seedling; the protein granules (*dp*) are plainly disintegrating; with the stain used, the nucleus first shows at this stage; ×600.

FIG. 7.—A cell from the spongy layer of a cotyledon of a 72-hour seedling; the hypocotyls of the seedlings have reached a length of 2.5–3.5 cm.; the protein grains have now disintegrated and the cell content has become very dense; the chloroplasts are beginning to increase by division; ×600.

FIGS. 8–11.—Cells from 84, 96, 108, and 120-hour seedlings; the increase in size and number of the chloroplasts at different stages can be plainly seen; during each succeeding stage the cell content becomes less dense and vacuoles appear; ×600.

FIG. 12.—A palisade cell from a cotyledon of a 140-hour seedling; the seedling has become independent and the cotyledon is a typical foliage organ; ×600.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BRIEFER ARTICLES

TWO SPROUTING CONIFERS OF THE SOUTHWEST

(WITH FOUR FIGURES)

The ability of conifers to produce coppice growth is limited to a few species, and most if not all of them occur in the United States. The coppicing of *Sequoia* has for a long time been a classic example, while sprout reproduction of the pitch pine (*Pinus rigida* Mill.) of the east and shortleaf pine (*Pinus echinata* Mill.) in the south is of considerable importance. During the past year extensive monogenetic reproduction of alligator juniper (*Juniperus pachyphloea* Torr.) and Chihuahua pine (*Pinus chihuahuana* Engelm.) was noted in the Garces National Forest along the international boundary between Mexico and the United States. This was very common for the region and was found in practically every stand where either of the species occurred.

The two most prominent stands of Chihuahua pine showing coppice origin were found in Boss Canyon in the Atascoso Mountains and to the south of the historic Mowry Mine in the Patagonia Mountains. The stand that occurs in Boss Canyon is especially prominent, since it extends the range for the species west of the Santa Cruz River and occurs at the remarkably low altitude of 1300 meters. Although an outlying body, it shows an optimum development for the species in the United States. According to a rough estimate, there are 500–600 Chihuahua pines over 15 cm. in diameter breast-high, with a reproduction that seems slightly inadequate to maintain the present stand. Fully two-thirds to three-fourths of the large seedlings and small saplings show severe injury by cattle, which usually consists of a broken leader and side branches (fig. 1). It is only rare seedlings in the most inaccessible areas that do not show this injury, and if it were not for the ability to sprout, reproduction would soon be missing. Typical sprouting over this area is confined to trees under 5 cm. in diameter, which send up most of the shoots from the root collar or the first 30 cm. above ground, although a large number of the saplings show groups of well formed buds at the nodes of both the leader and the branches. These buds occur for the most part on trees below 20 cm. in diameter at breast-height, and are usually confined to the lower half of the trunk and the lower portion of branches.

Near the Mowry Mine in the Patagonia Mountains there occurs a stand of Chihuahua pine which represents an excellent distribution of all sizes of trees up to 30 cm. in diameter and 9–15 meters tall. Many trees from 7.5 cm. up have been cut for mine timbers, and there is some

1 2

FIGS. 1, 2.—Fig. 1, Sprouts on Chihauhua pine as a result of injury by cattle; collected in Boss Canyon; fig. 2, Sprouts on Chihuahua pine as a result of forest fires; collected in Flux Canyon.

grazing injury. Not a single case was found where the stumps of trees smaller than 7.5 cm. in diameter had failed to produce thrifty sprouts, and fully 30–50 per cent of the stumps of trees up to 22.5 cm. in diameter had produced very thrifty sprouts, most of the fail stumps occurring

between the 15 and 22.5 cm. classes. It was only rarely that stumps over 22.5 cm. had produced any sprouts, while many stumps of 30 cm. and larger showed an entire lack of sprouting ability in older trees.

Recuperation after fire was well shown in Flux Canyon, which lies to the north of the Mowry Mine. A few scattering veterans had produced a fair amount of reproduction, which was mostly in the seedling stage. A severe ground fire which killed back several Emory oaks (*Quercus Emoryi* Torr.) and whiteleaf oaks (*Quercus hypoleuca* Engelm.) also killed back most of the Chihuahua pine reproduction. In every case where the dead leader of the pine remained, and in many cases where it was missing, 3–20 vigorous sprouts developed (fig. 2). It should not be inferred that this reproduction is more fire resistant than that of the oaks, for no information was available as to the amount and distribution of litter.

In the three stands already mentioned, as well as in various other places in the Patagonia Mountains, Canelo Hills, and Huachuca Mountains, a remarkable feature of the sprout growth was the early age at which cones were produced. A single case was found in Lyle Canyon where a tree 15 cm. in diameter breast-high and 7.5 meters tall was producing a green cone on an adventitious shoot only 30 cm. long which occurred 1.2 meters above ground. A few cases were found in which sprouts 7–10 years old were producing 1–3 cones each, and it was quite common to find sprouts 10–20 years old bearing 3–30 cones.

No study was made as to the relative rate of growth of sprouts and seedlings. Naturally the slow growth of the distinctly seedling period is not found in the sprout growth, but it is not known if the height growth of the sprouts culminates before the seedlings, as is the case with broad-leaved trees. No difference in form was noticed, although careful measurements might show a difference in form factor.

Even more remarkable is the sprouting of alligator juniper. In the northern portion of its range this species normally shows a large percentage of the trees with one or two shoots at the bases of the trees. These weak shoots are rarely over 15 cm. tall, and simply maintain life or die down, and are occasionally replaced by other equally weak shoots. In extensive trips over the Lincoln National Forest, where these small sprouts are common, not a single cut-over area showed any reproduction from the bases of the trees. There is a single tree between Capitan and Bonito, however, which was pollarded, and in May 1907 had 139 sprouts varying from 5 to 45 cm. in length (fig. 3). The same sort of sprouts were noted at the bases of trees in the Gila National Forest, but in the

vicinity of Gleed, Arizona, where rare specimens of the species occur, no sprouts were found.

Along the Mexican boundary this species is usually a minor one, but it probably reaches here the maximum individual development that occurs in the United States. For the most part, it is found in valleys and canyons and on terraces and slopes, closely associated with the evergreen oaks and usually extending somewhat beyond the upper limit

FIG. 3.—Root collar sprouts and pollard sprouts on alligator juniper as a result of cutting; Lincoln National Forest, N.Mex.

of Arizona white oak (*Quercus arizonica* Sarg.). Like the Chihuahua pine, this species is not grazed by stock except in cases of starvation, but it is greatly injured by cattle which run over it to brush off flies (fig. 4). A considerable amount of cutting has been done to furnish mine timbers and fence posts.

This species does not show adventitious buds as does the pine, but when cut or broken off, it shows a much stronger tendency to produce pollard sprouts or stump sprouts than does the pine, and usually shows fully as strong a development of root collar sprouts. Out of 50 cases

noted near Oro Blanco in Cedar Creek Canyon, where the trees range from 20–30 cm. in diameter at breast-height, 39 showed vigorous sprouting. The trees had been cut by the axe, and the stumps were 30–75 cm. in height. In this canyon a count of 100 trees, broken off by cattle, which had stump diameters of 2.5–5 cm., produced very strong sprouts, with the exception of two trees which had been killed outright. The sprouts ranged from 15 to 120 cm. in height, according to age, site, vigor of tree, and number of sprouts to the stump. The most noteworthy example was a stump 1 meter tall, 25 cm. top diameter, which had produced 3 sprouts from the top of the stump. These sprouts were 2 meters tall and had basal diameters of 3.75–6.25 cm.

On the west slope of the Patagonia Mountains another count of 50 stools showed only 6 failures; 4 were stumps which were over 20 cm. in diameter, and 2 had been killed by fire. All stumps below 5 cm. in diameter were producing thrifty sprouts. Two stumps 15 cm. in diameter and 30 cm. tall were producing respectively 63 and 166 sprouts, while a third stump 12.5 cm. in diameter and 35 cm. tall was supporting 256 sprouts. Generally 3–10 sprouts are produced on each stool, and not more than 1–3 of the sprouts continue to live and grow to tree size.

FIG. 4.—Sprouts on alligator juniper as a result of grazing; collected near Flux Canyon.

In Belmont Gulch, fully 95 per cent of all reproduction of alligator juniper showed serious injury by livestock, which was almost invariably followed by sprout recuperation. In the vicinity of the Mowry Mine and in the Huachuca Mountains the injury to reproduction varied from 80 to 100 per cent. Throughout the entire region examined, the species showed its ability to reproduce by coppice, especially when the trees were less than 20 or 22.5 cm. in diameter.

A few cases were noted where sprouts were producing fruit at a very young age. On the west side of the Patagonias, a stump 15 cm. tall and 0.6 cm. top diameter had produced a sprout 1.8 meters tall and 2.5 cm. base diameter. This sprout bore 14 fully formed berries. Again, near the mountain pass on the main road between Washington Mine and Nogales, several side branches had been cut from the crown of a mature alligator juniper, and the resulting sprouts, which were 8–13 years old, ranged from 30 to 60 cm. in length. Many of them were loaded with fully formed fruits.

The sprouting ability of both these species is a controlling influence in maintaining a satisfactory reproduction in this region. Many sprouts of Chihuahua pine were found which were 10–15 cm. base diameter and 4.5–6 meters tall, and a few were found 20–22.5 cm. base diameter and 9–10.5 meters tall. Many alligator juniper sprouts were noted which were 7.5–10 cm. at the base and 4.5–4.8 meters tall. All sprouts on both species are still making a thrifty growth.—F. J. PHILLIPS, *The University of Nebraska, Lincoln.*

CELL DIVISION IN LYNGBYA

(PRELIMINARY NOTE)

The form here described is a large salt water species occurring at Cold Spring Harbor, L.I., and answers to the description of *Lyngbya majuscula*. In a cell of *Lyngbya* there is a large central body or nucleus, which in the stages between divisions is, except for the absence of a limiting membrane, much like the resting nuclei of the higher plants. The nucleus contains a mesh of fine fibers along which small granules are scattered. The mesh is imbedded in a clear substance resembling nuclear sap. When treated with either Haidenhain's hematoxylon or Flemming's triple, the mesh stains like linin and the granules like chromatin. Although there is no membrane or definite boundary around the nucleus, it is quite distinct from the surrounding cytoplasm. The above description is quite similar to that which OLIVE[1] gives of the nuclei of some of the Cyanophyceae studied by him.

As a cell of *Lyngbya* approaches division, fine fibers appear around the nucleus in a plane perpendicular to the longitudinal axis of the filament. These fibers, which have an appearance closely similar to that of the spindle fibers of other plants, are very numerous, and run from

[1] OLIVE, E. W., Mitotic division of the nuclei of the Cyanophyceae. Beih. Bot. Centralbl. **18**:9–44. 1905.

the nucleus to the outer limits of the cytoplasm. They are all in practically the same plane, and thus form a plate across the center of the cell in the place where the cross wall, between the daughter cells, is to be produced. In several of his figures OLIVE shows fibers which appear quite like these. The stage just described, indeed, bears a close resemblance to his figs. 24–26 of *Oscillatoria*. However, since he does not describe these fibers in his text, or show them in longitudinal section, we cannot be sure how similar they are to those in *Lyngbya*.

At the end of each fiber in *Lyngbya*, there is laid down, against the cell wall, a small granule which stains black with Haidenhain's hematoxylon. These granules increase in size until they coalesce to form a ring around the center of the cell. This ring marks the place where the cross wall is to be formed, and it can still be seen, around the edge of this wall, after the wall has grown completely across the cell.

The production, at the place where the wall is to appear, of this ring by the fusion of granules formed at the ends of fibers which extend from the nucleus, would seem to indicate that the nucleus plays an important part in the formation of the wall, and that the nuclei of the Cyanophyceae may have functions similar to those of the nuclei of other plants. The presence of the fibers may indicate paths of conduction from the nucleus to the cell wall. DAVIS[2] describes a similar relation between the nucleus and the formation of the blepharoplast in the spores of *Derbesia*. Here strands radiate from the nucleus to the plasma membrane in the form of a funnel. According to this writer, "granules may be found on these strands apparently moving outwards towards the plasma membrane. These numerous granules accumulate in a circle just underneath the plasma membrane and fuse with one another to form a deeply staining firm ring, which is the blepharoplast."

In this discussion the central body of *Lyngbya* has been called a nucleus. This interpretation would seem to be justified by its structure and its relation to the formation of the cross wall.

The writer is indebted to Professor D. S. JOHNSON, in whose laboratory at the Johns Hopkins University the work was carried on, for material, and for other courtesies.—WILLIAM H. BROWN, *Michigan Agricultural College, East Lansing, Mich.*

[2] DAVIS, B. M., Spore formation in *Derbesia*. Annals of Botany **22**: 1–20. 1908.

CURRENT LITERATURE

BOOK REVIEWS

Intracellular pangenesis

DEVRIES'S *Intracellulare Pangenesis*, originally published in German in 1889, occupies an important position in the history of modern biology. It represents the fundamental speculations which guided the author in the experiments afterward reported in his great work *Die Mutationstheorie*, and it was also the first discussion presenting approximately the modern conception of unit characters.

Few scientists at the present time can accept in detail the scheme by which DEVRIES at that time explained the facts of heredity, but all appreciate the great value of this book in directing work along experimental lines, first by DEVRIES himself, and after him by a great number of both botanists and zoologists. While this work can scarcely be considered as having more than a historical significance at the present time, the triumph of the general principles introduced by it impresses the propriety of an English translation at the present time. This translation[1] has been satisfactorily made by GAGER. The translator points out in a brief preface the genetic relationship of "Intracellular pangenesis" to scientific conceptions now fully established upon an experimental basis.

A brief "Foreword" by STRASBURGER acknowledges his own indebtedness to the stimulating influence of DEVRIES, and observes that in a number of instances the speculative writings of that author both in *Intracellulare Pangenesis* and in the appended essay on *Befruchtung und Bastardirung* have proved prophetic of phenomena afterward actually found.

The translator has added occasional brief footnotes to explain certain allusions made by the author, or to call attention to more recent discoveries bearing upon the points under discussion. Several paragraphs have been omitted because there is no longer any necessity for speculation regarding the subject matter of those paragraphs. Purely as a historical work, the omission of these paragraphs seems to the reviewer to have been a mistake. It was impossible as well as undesirable to make the book contemporary science, though the desire to approximate this was undoubtedly the motive of the author and translator in making the omissions from the original work. Taking the place of these omitted paragraphs, the subjects involved in them are

[1] DEVRIES, H., Intracellular pangenesis, including a paper on fertilization and hybridization. Translated from the German by C. STUART GAGER. pp. xiii+270. Chicago: The Open Court Publishing Co. 1910.

treated in a paper on fertilization and hybridization read in Haarlem, Holland, by the same author in 1903. This essay is also modified from the original, being somewhat extended and brought more nearly down to date. It occupies the last 40 pages of the book, and presents a simple and interesting statement of the relation between modern cytological and genetic investigations as bearing upon the problem of unit characters.

Even in the brief time since this paper was revised for incorporation into this book, some of its subject matter has been given interpretations which render it unavailable for the particular application made, so that in at least one point it would need to be fundamentally rewritten. I refer particularly to the fact that the behavior of *Cytisus Adami* is taken as one of the clearest and simplest examples for demonstrating the existence of unit characters. Owing to the work of WINKLER and BAUR,[2] we now have a conception of this and other so-called graft hybrids which rules them out as examples of segregating unit characters.

Despite the fact that the book is neither strictly modern nor perfectly historical, it will be read with much profit by those interested in the subject of heredity and evolution, and all such will appreciate the work of GAGER in making this classic piece of speculation available to English readers.—GEO. H. SHULL.

A plant physiology

A treatise on plant physiology written by LECLERC DU SABLON[3] has many features of interest. One is impressed by the definite, concrete treatment of the subject. When a topic is considered, a great worker in that line is selected and his methods and results clearly stated. This leaves the student with a clear idea of the results, and how they were obtained. This method certainly has advantages over the usually concise but rather abstract statements for beginning students, and it might be desirable to have such a treatise in English. However, a statement of this kind must necessarily have its shortcomings, and they are unnecessarily increased in this work. It must omit many contributions, and this is shown in the present work by the preponderance of attention given to French investigators. French students using the text would probably conclude that France has been leading in plant physiology, and that SABLON is by no means the least of the producers.

The book can in no sense be considered critical. This objection the author answers by saying that he intentionally avoids unsettled questions and devotes the space to the well established phases of the subject. One is forced to believe that he could have given a more modern statement without running

[2] For an excellent review of the recent work on graft hybrids and chimeras, see BOTANICAL GAZETTE for February 1911.

[3] SABLON, LECLERC DU, Traité du physiologie végétale et agricole. vi+610. Paris: J. B. Bailliere et Fils. 1911.

unduly into unsettled questions. It would seem, for example, that a modern treatise on the subject ought to make some use of the masterly contributions of BROWN and ESCOMBE on the energy and material exchanges of the green leaf, and of FITTING'S telling work on geotropism.

The order of treatment differs from that of most English and German works. The headings of the chapters are as follows: (1) nutritive reserves; (2) respiration; (3) fermentation; (4) assimilation of carbon; (5) mineral nutrition; (6) circulation of water; (7) transpiration; (8) latent life and development; (9) movements; (10) influences of environment; (11) physiology of the species.

The agricultural significance of the subject is emphasized. In the main this is done by using data gained from a study of the economic plants. The book is not indexed, but this is partly cared for by a full table of contents.—WILLIAM CROCKER.

MINOR NOTICES

Das Pflanzenreich.[4]—Part 43 contains the first portion of a monographic treatment of the Umbelliferae by Dr. HERMANN WOLFF. The present part includes 9 genera of the tribes *Apioideae* and the heteroclitus *Ammineae*, to which are referred about 150 species. The body of the publication is occupied mainly with the genus *Bupleurum*, which is represented by approximately 100 species, nearly all occurring in the northern hemisphere. One new genus (*Ledebouriella*) is proposed, being based on *Rumia multiflora* Ledeb. of uncertain native habitat and *R. seseloides* Hoff. from the Altai.

Part 44 continues the elaboration of the Euphorbiaceae by Professor F. PAX and concerns only the tribe *Adrianeae*. The author recognizes 8 genera and 144 species, of which 34 are new to science. One new genus (*Cephalocrotonopsis*) is described, founded on *Cephalocroton socotranus* Balf. f. from the steppes of northern Africa. Of the 8 genera constituting the tribe, the genus *Manihot* comprises by far the largest number of species (129), and these have their center of distribution in Brazil.

Part 45 is devoted to a monographic consideration of the tribe *Dendrobiinae* of the Orchidaceae by the noted specialist Professor FR. KRÄNZLIN. Seven genera are elaborated, the first in importance being *Dendrobium*. This genus, as here treated, includes approximately 600 species, numerous varieties, and over 80 hybrids; and its greatest specific diversity is in the Monsoon region of the Old World. The genus is divided into ten subgenera which are

[4] ENGLER, A., Das Pflanzenreich. Heft 43 (IV. 228). Umbelliferae-Apioideae-Bupleurum, Trinia et reliquae Ammineae heteroclitae von HERMANN WOLFF. pp. 214. *figs. 24* (*155*). *M* 10.80. Heft 44 (IV. 147. II). Euphorbiaceae-Adrianeae von F. PAX. pp. 111. *figs. 35* (*151*). *M* 5.70. Heft 45 (IV. 50. II. B. 21). Orchidaceae-Monandrae-Dendrobiinae von Fr. KRÄNZLIN. pp. 382. *figs. 35* (*327*). *M* 19.20. Leipzig: Wilhelm Engelmann. 1910.

based on the general character of the stems, leaves, and inflorescence. About 50 of the species recorded are new to science. The excellent keys, full descriptions, and numerous habital and detailed illustrations render this an exceedingly important treatise on a most difficult but highly interesting group of plants.—J. M. GREENMAN.

The Australian pines.—An elaborate volume records the results of the labors of BAKER and SMITH[5] in studying the "pines of Australia." Curiously enough, there are no pines in Australia, the Abietineae being the only one of the six tribes of conifers unrepresented. The feature of the book is the wealth of illustrations, almost all of which are reproductions of photographs, many of which were made by the natural color process. The technical skill shown in this photographic work is to be highly commended, and probably in no other publication have conifers such a setting. The motive of the work is confessedly economic, and this aspect of the Australian conifers is doubtless presented with a completeness that leaves little to be desired. It seems that *Callitris*, next to *Eucalyptus*, is the most important genus of Australian trees; and the authors have indicated its complete generic separation from *Widdringtonia* of South Africa and *Tetraclinis* of North Africa, which makes it a genus restricted to Australia and Tasmania. In presenting the eleven genera of the region, the authors include so many details of structure and of products that the volume is a thesaurus of observations for those who are in a position to estimate their value. In the presentation of each species, after an account of its history and its taxonomic characters, there are described fully the economics, anatomy, and chemistry of leaves, fruits, timber, and bark.—J. M. C.

Conservation.—Because of the loose talk current concerning the conservation of our resources, it is well to have an authoritative treatise on the subject by one of acknowledged competence. Such a treatise is the one from the hand of President VAN HISE of the University of Wisconsin,[6] which is based on lectures before students. Botanists will be interested especially in the chapter on forests, and in the one on land, in which soil conservation is considered. The author's expert training as a geologist fits him peculiarly for his consideration of the mineral resources, and scarcely less so for his treatment of the soils. The final chapter deals with conservation and mankind, and there are three appendices, which give declarations of conservation principles as set forth by various organizations.—H. C. COWLES.

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[5] BAKER, RICHARD T., and SMITH HENRY, G., A research on the pines of Australia. Technological Museum, New South Wales. 4to. pp. xiv+458. *figs. 300. maps 3.* Sydney: Government Printer. 1910.

[6] VAN HISE, C. R., The conservation of natural resources in the United States. 8vo. pp. xiv+413. *pls. 16.* New York: The Macmillan Co. 1910. $2.00.

Natürlichen Pflanzenfamilien.[7]—Parts 241 and 242 continue the supplement to the algae. One new genus (*Pseudolithoderma*) of the Lithodermataceae is proposed, which is based on *Lithoderma fatiscens* Kuck. not Aresch. —J. M. GREENMAN.

NOTES FOR STUDENTS

Current taxonomic literature.—J. C. ARTHUR (Bull. Torr. Bot. Club **37**:569–580. 1910) under the title "New species of Uredineae VII" has described 13 new species.—H. H. BARTLETT (U.S. Dept. Agr. Bur. Pl. Ind. Bull. No. 189. pp. 29. 1910) presents the results of a study of the *Dioscoreae* of the United States, and in a detailed synopsis recognizes 5 species, 2 of which and one variety are new to science.—M. BOULY de LESDAIN (Bull. Soc. Bot. Fr. IV. **10**:460–463. 1910) has published several new species of lichens, including 2 from Mexico.—E. BRAINERD (Bull. Torr. Bot. Club **37**:523–528. *pls. 34, 35*. 1910) has described 5 new species of the genus *Viola* from the southern states.—V. F. BROTHERUS (Phil. Journ. Sci. Bot. **5**:137–162. 1910) in a third "Contribution to the bryological flora of the Philippines" enumerates 91 genera and 143 species; one monotypic genus (*Pseudoracelopus*) and 27 species belonging to several different genera are recorded as new.—C. DECANDOLLE (Leafl. Phil. Bot. **3**:759–789. 1910) under the title "Philippine Piperaceae" records 50 recognizably distinct species, varieties, and forms of *Peperomia* and *Piper*, more than one-half of which are new to science.—J. CARDOT (Rev. Bryol. **37**:65–72. 1910) in an article entitled "Diagnoses préliminaires de Mousses mexicaines" has published several new species.—E. B. COPELAND (Phil. Journ. Sci. Bot. **5**:283–285. 1910) in an article entitled "Additions to the Bornean fern flora" has published a variety and several new species of ferns, and proposes a new genus (*Protolindsaya*).—H. N. DIXON (Journ. Bot. **48**:297–310. *pls. 507, 508*. 1910) presents a paper on Indian mosses and includes several species new to science. One new genus (*Merceyopsis*) of the Pottiaceae is characterized, which is said to be intermediate between *Merceya* and *Hyophila*, and is represented by 7 known species.—S. T. DUNN (Kew Bull. 386, 387. 1910) has published a new genus (*Leptoderris*) of the Leguminosae from tropical Africa, and gives a key to the 14 known species.—A. D. E. ELMER (Leafl. Phil. Bot. **2**:703–728. 1910) records 30 species of Lauraceae from Mt. Apo and Mt. Giting-Giting, P.I., 18 of which are designated as new. The same author (*ibid.* 729–734) lists 6 species of *Solanum* from Mt. Apo, of which 4 are new; and (*ibid.* 735–740) describes 5 new species of the genus *Begonia* from the Philippines.—J. S. GAMBLE (Kew Bull. 218–228. 1910) in

[7] ENGLER, A., and PRANTL, K., Die natürlichen Pflanzenfamilien, etc. 241. und 242. Lieferungen. Chlorophyceae von N. WILLE. Phaeophyceae und Dictyotales von F. R. KJELLMAN und N. SVEDELIUS. Rhodophyceae von N. SVEDELIUS. Nachträge zum I. Theil, 2. Ab. pp. 97–192. *figs. 54 (174)*. Leipzig: Wilhelm Engelmann. 1910. *M* 6.

a paper on "New Lauraceae from the Malayan Region II" includes the description of a new genus (*Stemmatodaphne*). The same author (Phil. Journ. Sci. Bot. **5**:267–281. 1910) under the title "Bamboos of the Philippine Islands" enumerates 7 genera to which are referred 25 species, 12 being new to science.—A. O. GARRETT (Mycologia **2**:265–304. 1910) in an article entitled "The smuts and rusts of Utah" publishes a catalogue of these plants collected in seven different counties of Utah, during eight years of field work, recording 144 species.—M. GÜRKE (Monats. für Kakteenkunde **20**:145–148. 1910) characterizes a new species of *Cereus* (*C. pseudosonorensis*); the plant has been brought into cultivation in European gardens along with *C. sonorensis* from Mexico.—E. HACKEL (Rep. Nov. Sp. **8**:513–523. 1910) has published several new species of Gramineae, 5 of which are from Mexico and South America. The author also describes a new monotypic genus (*Anelytrum*), found near Genoa, Italy, the native habitat of which is still in doubt.—H. HARMS (Bot. Jahrb. **45**:293–316. 1910) under the heading "Leguminosae africanae V" has published 27 new species and records two genera (*Eurypetalum* and *Tessmannia*) new to science.—E. HASSLER (Rep. Nov. Sp. **8**:552–560. 1910) continues the enumeration of plants of Paraguay, publishing several new species and varieties in the Leguminosae.—A. A. HELLER (Muhlenbergia **6**:97–113. 1910) gives further results of his studies of "The Nevada lupines" and describes two new species (*L. montigenus* and *L. nevadensis*).—J. HERZOG (Beih. Bot. Centralbl. **27**^{2}:348–358. 1910) has published 11 new species of mosses from Bolivia.—B. P. G. HOCHREUTINER (Bull. N.Y. Bot. Gard. **6**:262–299. 1910) under the title "Critical notes on new or little known species in the Herbarium of the New York Botanical Garden" has published 27 new species and varieties of flowering plants, mostly from South America.—J. HUBER (Bol. Mus. Goeldi **6**:60–90. 1910) in an article entitled "Novitates florae Amazonicae" has published 31 new species of flowering plants from the region of the Amazon; the paper includes a new genus (*Euxylophora*) of the Rutaceae.—F. KRÄNZLIN (Rep. Nov. Sp. **8**:545. 1910) has published a new species of *Cleisostoma* (*C. chrysochilum*) from the Philippines.—G. LISTER (Journ. Bot. **48**:310–312. 1910) has described a new genus (*Colloderma*) belonging to the Mycetozoa; it is based on *Didymium oculatum* Lippert, which was originally found in upper Austria and rediscovered near Skene, Aberdeenshire, Scotland.—J. LUNELL (Am. Mid. Nat. **1**:204–208, 233–238. 1910) has described 7 new species and several varieties of spermatophytes from North Dakota.—K. K. MACKENZIE (Torreya **10**:249, 250. 1910) records a new species of *Proserpinaca* (*P. intermedia*) at present known only from New Jersey and Georgia, and (*ibid.* 228–230) a new blueberry (*Vaccinium caesariense*) from New Jersey.—P. MAGNUS (Ber. Deutsch. Bot. Gesell. **28**:377–380. *pl. 11.* 1910) describes and illustrates a hitherto unknown parasitic fungus from the Transvaal; the fungus was found on stems of *Zizyphus* and a new genus has been created for it, namely *Hyalodema*.—G. MASSEE (Kew Bull. 249–253. 1910) describes several new fungi and includes a new *Merasmius* from Trini-

dad, a new *Polyporus* from Louisiana, and a new genus (*Pilula*) from tropical Africa.—E. D. MERRILL (Phil. Journ. Sci. Bot. **5**:1–136. 1910) has published an "Enumeration of Philippine Leguminosae with keys to the genera and species," recognizing 90 genera and about 280 species of this family in the Philippine Islands; one new genus (*Monarthrocarpus*) is proposed, being based on *Desmodium securiforme* Benth; 15 species and 4 varieties are new to science and several new combinations are made. The same author (*ibid.* 167–257) under the title "New or noteworthy Philippine plants VIII" has published 104 new species of flowering plants and proposes the following new genera: *Curraniodendron* of the Saxifragaceae, *Astrocalyx* and *Cephalomedinella* of the Melastomaceae, and *Pygmaeopremna* of the Verbenaceae.—E. D. MERRILL and M. L. MERRITT (*ibid.* 287–370) begin a consideration of "The flora of Mount Pulog," one of the highest mountains of the Island of Luzon. The present article gives a general descriptive account of the island, characterizing four floral regions, or types of vegetation, and enumerates the plants from the Hepaticae to the Umbelliferae. The paper contains descriptions of two new genera (*Aniselytron* and *Monostachya*) of the Gramineae and 21 new species belonging to different genera of flowering plants.—W. A. MURRILL (Mycologia **2**:305. 1910) has described a new boletus (*Gyroporus jamaicensis*) from Jamaica.—J. A. NIEUWLAND (Am. Mid. Nat. **1**:263, 264. 1910) proposes a new genus (*Bataprine*) based on *Galium hispidulum* Michx.—C. H. OSTENFELD (Ber. Deutsch. Bot. Gesell. **28**:397–400. 1910) has published a new genus (*Thorosphaera*) of the Coccolithophoraceae; the material on which the genus is based was collected in the Mediterranean Sea near Calabria.—S. B. PARISH (Muhlenbergia **6**:113–128. 1910) presents a useful synopsis of "The Southern California Juncaceae" with keys to the genera and species.—F. PAX (Bot. Jahrb. **45**:234–241. 1910) under the title "Euphorbiaceae africanae XI" has published several new species and characterizes two new genera, namely *Zimmermannia* and *Excoecariopsis*.—F. PETRAK (Beih. Bot. Centralbl. **27**^{2}:207–255. *pls. 1, 2.* 1910) under the title "Die mexikanischen und zentralamerikanischen Arten der Gattung Cirsium" presents an interesting revision of the group, recognizing 27 species. The study is based on the material in the Royal Museum of Natural History in Vienna.—L. QUEHL (Monats. für Kakteenkunde **20**:149–150. 1910) describes and illustrates a new species of *Mamillaria* (*M. bombycina*) from Mexico.—A. REHDER (Mitt. Deutsch. Dendr. Gesell. 1910, pp. 248–254) in an article entitled "Einige neue und kritische Gehölze" publishes a hitherto unrecorded form of *Ribes Cynosbati* from Vermont and West Virginia, a new form of *Rosa pratincola* from Central United States, and three new hybrids in the genus *Hypericum*.—H. H. RUSBY (Bull. N.Y. Bot. Gard. **6**:487–517. 1910) has described 67 new species of flowering plants from Bolivia, based on collections made by R. S. WILLIAMS in 1901 and 1902.—P. A. RYDBERG (Bull. Torr. Bot. Club **37**:541–557. 1910) in continuation of his "Studies on the Rocky Mountain flora" has described 4 new species of *Carduus*.—C. S. SARGENT (Proc. Acad. Phila. **62**:150–253. 1910)

under the title "Crataegus in Pennsylvania II" records 110 species of this genus from Pennsylvania, 79 of which are indicated as new.—R. SCHLECHTER (Rep. Nov. Sp. **8**:561–572. 1910) under the title "Orchidaceae novae et criticae" has published 19 new species of orchids, several being from America; one new genus (*Platystele*) is proposed, which is based on PITTIER'S no. 2013 from Costa Rica.—J. K. SMALL (Torreya **10**:230, 231. 1910) has described a new species of *Anychiastrum* (*A. montanum*) from the mountains of southern Pennsylvania to Georgia.—I. URBAN (Symb. Ant. **4**:353–528. 1910) continues the "Flora portoricensis." The present fascicle contains the genera from *Euphorbia* to *Verbena* and includes a new species of *Heliotropium* (*H. antillanum*) from Porto Rico and Cuba, and a new variety of *Jussiaea suffruticosa* L.—W. WEINGART (Monats. für Kakteenkunde **20**:161, 162. 1910) has published a new species of *Cereus* (*C. cinnabarinus* Eichlam) from Guatemala.—R. S. WILLIAMS (Bull. N.Y. Bot. Gard. **6**:227–261. 1910) in a second contribution on Bolivian mosses records approximately 200 species and varieties, and of these 19 are described as new.—H. L. WILSON (Univ. Calif. Pub. Bot. **4**:75–84. *pls. 12, 13.* 1910) in conjunction with W. A. SETCHELL has published a new genus (*Gracilariophila*) parasitic on *Gracilaria confervoides*. The host and parasite have the same subordinal relationship.—H. WINKLER (Bot. Jahrb. **44**:497–571. 1910) has published the first of a series of articles entitled "Beiträge zur Kenntniss der Flora und Pflanzengeographie von Borneo." The paper is based mainly on collections made by WINKLER in 1908, and in the work of identification the author has been assisted by eminent specialists. About 45 new species are here described for the first time, and one new genus (*Campanocalyx*) of the Rubiaceae is included.—H. WOLFF (Rep. Nov. Sp. **8**:524–526. 1910) under the title "Umbelliferae novae I" has described new species from Mexico and China.—Different authors (Kew Bull. 328–344, 368–371, 381–386. 1910) have published new species of flowering plants, chiefly from Africa but including several from Peru. One new African genus (*Necepsia*), belonging to the tribe *Crotoneae* of the Euphorbiaceae, is proposed by D. PRAIN.—J. M. GREENMAN.

Algal coals.—The characteristic petroleum-yielding coals known as boghead, cannel, etc., have been referred to an algal origin by RENAULT, BERTRAND, and POTONIÉ, a view that has been more or less acceptable to our own students of paleozoic coals. The evidence of such an origin is the occurrence in such coals, as well as in bituminous schists and oil-shales, of abundant "spherical or oval bodies, often arranged in layers," these bodies being interpreted as colonial algae. They have now been investigated by JEFFREY,[8] who developed a special technique to secure numerous and even serial thin sections. As a consequence, the structure and hence the nature of these bodies have been brought out with a clearness not heretofore possible.

[8] JEFFREY, E. C., The nature of some supposed algal coals. Proc. Amer. Acad. **46**:273–290. *pls. 5.* 1910.

They are certainly not algae, but spores of pteridophytes, a group which constituted an important part of the paleozoic vascular flora, and which has always been regarded as responsible, to a large extent at least, for the ordinary coals. This conclusion sets aside the algal hypothesis of the origin of petroleum and other substances, and refers such products to the waxy and resinous spores of pteridophytes, "laid down on the bottoms of the shallow lakes of the Coal Period. These lacustrine layers, either as cannels, bog-heads, or bituminous shales, according to the sporal composition and the admixture of earthy matter, are the mother substance of petroleum. Pressure and temperature, either separately or combined, in the presence of permeable strata, have brought about the distillation of petroleum from such deposits."—J. M. C.

Alkaloids and algae.—COMÈRE[9] finds that some alkaloids can be used by algae as the only source of nitrogen. The algae used were *Ulothrix subtilis* and *Spirogyra crassa*, and the alkaloids were morphine hydrogen chloride, atropine sulphate, cocaine hydrogen chloride, quinine hydrogen chloride, and strychnine sulphate. The alkaloids were added gradually as assimilated, so that the plants were never subjected to strong solutions. *Ulothrix* proved to be far more amenable to cultural conditions than *Spirogyra*. It can readily assimilate morphine and atropine, and less readily cocaine; *Spirogyra* showed less marked assimilation of these compounds. Quinine could not be assimilated by either, and strychnine was very toxic to both, even in great dilution. Some of the alkaloids, therefore, are not aplastic.—WILLIAM CROCKER.

Response to light.—DANGEARD[10] finds that in three species of *Chromatium* studied (*C. Okenii*, *C. vinosum*, *C.* sp.?) there is a marked accumulation in the longer rays of the spectrum as observed by ENGELMANN. In the infra-red there are two regions of accumulation; one in ray lengths 0.840–0.820 μ, and the second at 0.800–0.790 μ. In the visible spectrum there is a zone of accumulation between the *B* and *C* lines, and a second one extending to each side of the *D* line. A green bacterium that he recently described also responds to longer rays; it accumulates in a zone with ray lengths 0.770–0.670 μ. Some other experiments, claimed to show the relatively great effectiveness of long rays in assimilation and growth, add nothing of value to our knowledge. —WILLIAM CROCKER.

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[9] COMÈRE, JOSEPH, Du rôle des alcaloides dans la nutrition des algues. Bull. Soc. Bot. France **57**: 277–280. 1910.

[10] DANGEARD, P. A., Phototactisme, assimilation, phénomènes de croissance. Bull. Soc. Bot. France **57**: 315–319. 1910.

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